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PHOTOGRAPHS AND DESCRIPTIONS OF CUP-FUNGI—XIV[1]

A NEW GENUS

FRED J. SEAVER

(WITH PLATES 23 AND 24)

In November, 1911, the writer sent to Dr. H. Rehm of Germany among other things a cup-fungus on the foliage of white cedar from Montana. On January 7, 1912, Rehm reported on this species which he called *Helotium Seaveri* Rehm, n. sp. Although Rehm lived until April 1, 1916, and continued to publish up to 1914, the writer has been unable to find any record of the publication of this species, although it is possible that it may have been published by him. The material was filed away in the collection until recently when it became subject to rather critical study.

In working over the inoperculate cup-fungi, preparatory to a monograph, the writer has encountered a second species, on leaves of *Sequoia* from California, with characters very similar to those of our own. The form on *Sequoia* was described by Phillips and Harkness as *Peziza chloromela*. Saccardo later transferred this to *Chlorosplenium* because of the greenish color of the apothecia. This and the preceding are without question congeneric although they can scarcely be regarded as belonging to the genus *Chlorosplenium*.

[1] This paper is preliminary to a monograph of North American Cup-fungi (inoperculates), a companion volume to North American Cup-fungi (operculates) which was published by the author and issued in December, 1928.

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On further investigation a third species was found in the collection described by Ellis as *Dermatea juniperina* on leaves of *Juniperus communis* from Iowa. This again appears to be congeneric with the other two although the spores are somewhat different in form.

In December, 1930, the writer received from Dr. H. S. Jackson of Toronto, Canada, a fourth species on *Thuja occidentalis* which is very similar to our own form on *Thuja* but with spores which are much more slender and apothecia which are stipitate instead of sessile or subsessile. All of the four species occur on the foliage of coniferous trees and all are apparently parasitic. Since they have much in common and do not fit well in any of the known genera the writer proposes to establish a new genus for these forms. It seems very likely that other forms will be brought to light on further investigation. The name *Chloroscypha* is suggested by the fact that the apothecia are decidedly yellowish-green by transmitted light. They belong to the inoperculate section of the cup-fungi.

CHLOROSCYPHA Seaver, gen. nov.

Apothecia gregarious or scattered, sessile or stipitate, minute or of medium size, yellowish-green to blackish when dry, the substance yellowish-green by transmitted light and resembling that of *Ascobolus*, occurring on the foliage of conifers, *Thuja*, *Sequoia*, and *Juniperus*, and apparently parasitic; asci when young greenish, normally 8-spored; spores comparatively large, at first granular and appearing greenish, but hyaline when mature, typically fusiform or more rarely broad-ellipsoid; paraphyses slender, simple or branched, surrounded by a greenish matrix.

Type species, *Helotium Seaveri* Rehm.

Occurring on foliage of *Thuja*.	
Apothecia subsessile; spores broad-fusoid.	1. *C. Seaveri.*
Apothecia stipitate; spores narrow-fusoid.	2. *C. Jacksoni.*
Not on *Thuja*.	
On *Sequoia;* spores fusoid.	3. *C. chloromela.*
On *Juniperus;* spores broad-ellipsoid.	4. *C. juniperina.*

1. **Chloroscypha Seaveri** (Rehm) Seaver, comb. nov.

Helotium Seaveri Rehm (in litt.). 1912.

Apothecia minute, scarcely exceeding .5 mm. in diameter, subsessile, occurring singly or in small cespitose clusters on the leaves of the host, turbinate, greenish, becoming almost black in dried material; hymenium plane or nearly so, lighter than the outside of the apothecium, the substance of the apothecium pale olivaceous-green when teased out and viewed by transmitted light; asci clavate, reaching a length of 100–135 μ and a diameter of 25–30 μ, the contents greenish, 8-spored; spores irregularly 2–3-seriate, fusoid to fusiform, the lower end often more pointed than the upper, densely filled with granules and slightly yellowish-green, about 8–9 $\times$ 25–28 μ, smooth or very minutely roughened; paraphyses filiform, scarcely enlarged above.

On foliage of white cedar, *Thuja plicata*.

Type locality: Libby, Montana.

Distribution: Known only from the type locality.

According to J. R. Weir, this fungus causes a very destructive blight. This species appears to be very closely related to the previously described *Chlorosplenium chloromelum* which occurs on the foliage of *Sequoia sempervirens* in California.

2. **Chloroscypha Jacksoni** Seaver, sp. nov.

Apothecia scattered, stipitate, at first closed, gradually opening and becoming shallow cup-shaped, then discoid, externally yellowish furfuraceous, becoming darker with age, reaching a diameter of 2 mm.; hymenium concave, plane or slightly convex, yellowish with a greenish tint, often becoming nearly black with age; stem slender, reaching a length of 2 mm., similar in color to the outside of the apothecium; asci clavate, reaching a length of 100–110 μ (rarely 130) and a diameter of 12–14 μ, 8-spored; spores irregularly 2-seriate, fusoid or fusiform, often with two distinct oil-drops or granular, often apparently greenish when young, usually hyaline when mature, and often minutely roughened or smooth, 6–7 $\times$ 20–28 μ; paraphyses slender, rather abruptly enlarged above and surrounded with a greenish-yellow substance.

On *Thuja occidentalis*.

Type locality: Temagami Region, Canada (Jackson, *2047*).

Distribution: Known only from the type locality.

This species differs from the preceding, which also occurs on *Thuja*, in the much narrower spores and stipitate apothecia. Whether this species is also parasitic has not been determined.

3. **Chloroscypha chloromela** (Phill. & Hark.) Seaver, comb. nov.

Peziza chloromela Phill. & Hark. Grevillea **13**: 22. 1884.

Chlorosplenium chloromelum Sacc. Syll. Fung. **8**: 319. 1889.

Apothecia scattered or gregarious, short-stipitate, externally smooth, greenish-black, reaching a diameter of .6 mm.; hymenium becoming nearly plane, yellowish-green; stem reaching a length of 1 mm., a little paler than the outside of the apothecium; asci clavate cylindric; spores clavate or fusiform, usually curved, at first hyaline, becoming greenish, 4–5 × 20–25 μ; paraphyses filiform, indistinct, adhering together.

On leaves of *Sequoia sempervirens*.

Type locality: California.

Distribution: Known only from the type locality.

A note from the Royal Botanic Gardens states that the material of *Peziza chloromela* at Kew is very scanty. Through the kindness of the Director of that institution a microscopic slide has been examined. The spores as indicated in the description are smaller than in the species on white cedar.

4. **Chloroscypha juniperina** (Ellis) Seaver, comb. nov.

Dermatea juniperina Ellis, Am. Nat. **17**: 192. 1883.

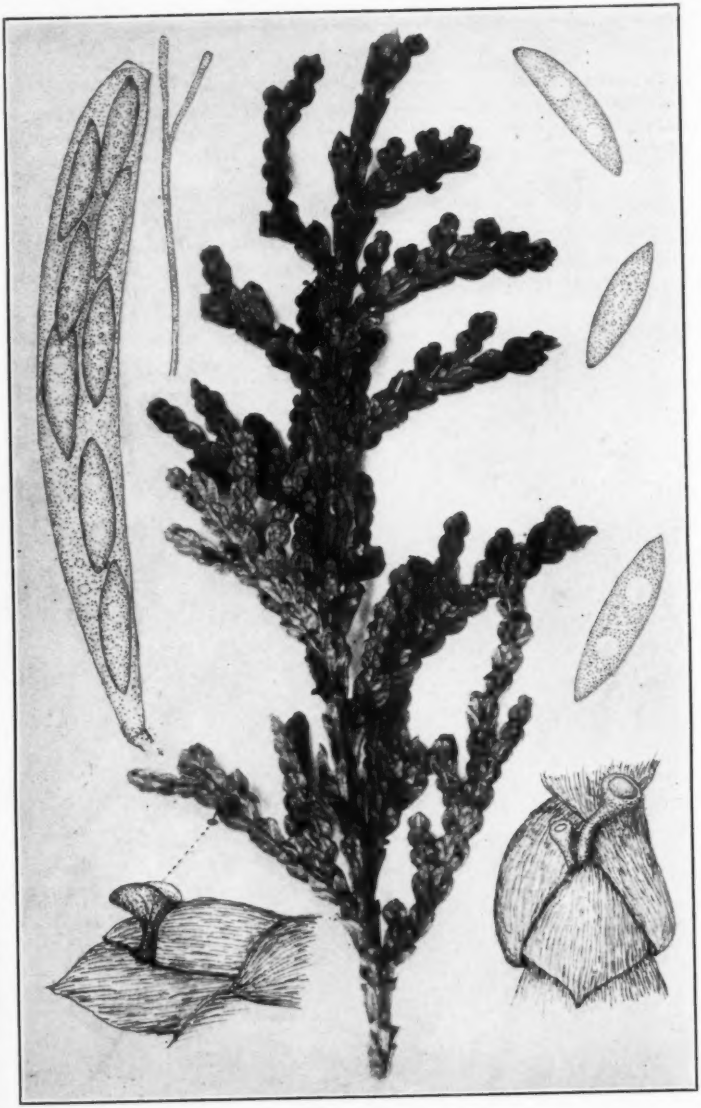
Apothecia gregarious, at first rounded, expanding and becoming turbinate, tapering into a stem-like base, black to the unaided eye, greenish with transmitted light, reaching a diameter of .25 mm.; asci clavate, reaching a length of 130 μ and a diameter of 20 μ, tapering rather abruptly below; spores ellipsoid or fusoid, about 9–10 × 18–20 μ, granular within, often appearing greenish from the greenish material which surrounds the asci and paraphyses; paraphyses slender, enlarged above, reaching a diameter of 4 μ, adhering together at their tips, yellowish-green.

On leaves of *Juniperus communis*.

Type locality: Decorah, Iowa.

Distribution: Known only from the type locality.

This species is quite similar in general appearance to *Chlorocypha Seaveri* but differs in the form and size of the spores as well as in the host.



CHLOROSCYPHA JACKSONI

EXPLANATION OF PLATES

PLATE 23

Chloroscypha Seaveri. Center, photograph of foliage of white cedar, *Thuja plicata*, with fungus, slightly enlarged. Left, ascus with paraphyses and spores. Right, drawing of a piece of foliage showing distribution of apothecia much enlarged. Below, sketches of apothecia much enlarged and drawings of two ascospores.

PLATE 24

Chloroscypha Jacksoni. Center, photograph of branch of *Thuja occidentalis* with fungus, about twice natural size. Left, drawing of ascus with spores and paraphysis. Right, drawing of several spores isolated. Below, sketches of portions of foliage with apothecia much enlarged.

Drawings of asci, spores and paraphyses were made with the aid of the camera lucida.

TAXONOMIC STUDIES IN THE FAMILY PYTHIACEAE

I. NEMATOSPORANGIUM [1]

C. P. Sideris

(With 12 Text Figures)

Introduction

The studies presented herewith and in a series of papers to follow are the outcome of pathological investigations on a root-rot disease of pineapple plants known as pineapple wilt. As various microorganisms were isolated it became evident that many of them were undescribed members of the family Pythiaceae. Subsequent inoculations of roots of pineapple and certain other plants with these organisms proved that most of them are either weakly or aggressively pathogenic. In the attempt to identify them through the literature it was found that such literature was inadequate for the purpose.

This paper takes up first a review of the entire family Pythiaceae and points out the justification in the writer's opinion for reëstablishing *Nematosporangium* as a genus. It then takes up specifically those of the fungi isolated that fall into this group, classifies them by means of morphological and cultural characters, and gives detailed descriptions of all new species. The technique on the isolation and pathogenicity of the different organisms is discussed in another paper, which will soon be published.

Family Pythiaceae

The family Pythiaceae, one of the three included in the order Peronosporales, is differentiated from the other two, namely, the Albuginaceae and the Peronosporaceae, by certain morphological features of the asexual reproduction of its members. The members of the family Pythiaceae lack a definite conidio-

[1] Technical paper No. 19 of the Experiment Station of the Association of Hawaiian Canners, University of Hawaii.

phore, whereas those of the other two families possess well defined conidiophores.

The family is divided by certain investigators (**2, 9**) into the genera *Pythium* and *Phytophthora*, and by others (**11, 12**) into the genera *Nematosporangium* and *Pythium*. The tendency on the part of the first group of mycologists is to incorporate the genus *Nematosporangium* in the genus *Pythium*, and on the part of the other, to place the genus *Phytophthora* in the family Peronosporaceae owing to the well differentiated conidia and conidiophores of some species of this genus.

The members of the genus *Nematosporangium* never produce conidia and those of *Pythium* possess only pseudo- or atypical conidia, that is, asexual reproductive organs that do not fall off the supporting hypha to grow vegetatively, but germinate while attached to the hypha. The members of the other two families possess euconidia or typical conidia. The genus *Phytophthora* occupies a very doubtful position, as some of its members produce both euconidia and pseudoconidia (chlamydospores). The pseudoconidia of spherical shape are produced more abundantly in old cultures and behave as resting spores and, in the majority of cases, remain attached to their supporting hypha. The euconidia of oval shape are produced in a greater degree in young and in a lesser degree in old cultures, and become mostly zoösporangia. They may or may not fall off their supporting hypha.

Phytophthora, therefore, occupies a transitional position between the Pythiaceae, on the one hand, and the Peronosporaceae, on the other. It is on account of these and other morphological characters that it is placed by some in the former and by others in the latter family. The writer's critical study of the situation indicates that *Nematosporangium* merits generic recognition, owing to many basic morphological and physiological differences separating the members of this genus from those of *Pythium*.

Fischer (**7**) divided the genus *Pythium* into the subgenera *Aphragmium*, *Nematosporangium* and *Sphaerosporangium*. The prosporangia of the first two are nematoid or allantoid but never or very seldom spherical; whereas those of *Sphaerosporangium* are always spherical to lemon-shaped. The difference between *Aphragmium* and *Nematosporangium* is in the septation of the

exit tube of the prosporangium supporting the zoösporangium. This difference has been found later to be of small importance and too insignificant to merit subgeneric recognition. Butler (**2**), who studied Fischer's organism *Pythium complens* and Schenk's *P. gracile*, and de Bary's *P. reptans*, which Fischer used as type specimens for the creation of the subgenera *Aphragmium* and *Nematosporangium*, states the case as follows: "I have had what is certainly de Bary's *P. gracile*, as well as the species which I have identified with Schenk's organism, in culture for many months, and have never observed the sporangia to be cut off, though the accidental appearance of this, as described under *P. monospermum*, was not rare. Fischer (1892, p. 398) also agrees with Schenk that septa are absent." Schröter (**12**) on the basis of Fischer's later findings, that is, that there were no morphological differences separating the subgenera *Aphragmium* and *Nematosporangium*, incorporated these two subgenera under the name *Nematosporangium* and raised the subgenus *Nematosporangium* to generic rank. Butler (**2**), although aware of Schröter's classification, admitted Fischer's original classification and suggested the incorporation of the subgenera *Aphragmium* and *Nematosporangium* in the subgenus *Aphragmium*, on the basis that "the validity of the character on which the subgenus *Nematosporangium* was founded in *Pythium monospermum* by Fischer is doubtful and under the circumstances it seems unnecessary to separate this species from the *Aphragmia*." Lindau (**11**) retains the original classification of Schröter, recognizing the generic rank of *Nematosporangium*. Fitzpatrick (**8**) suggested, in 1923, the generic name *Nematosporangium* in preference to *Pythium* in the organism *Pythium aphanidermatum* (Edson) Fitz. Gaüman (**9**) has adopted the original classification of Fischer as modified by Butler.

COMPARATIVE MORPHOLOGY OF NEMATOSPORANGIUM, PYTHIUM AND PHYTOPHTHORA

Butler (**2**) discusses with great thoroughness the morphological characters of a considerable number of species of the subgenera *Aphragmium*, *Nematosporangium*, and *Sphaerosporangium* of the genus *Pythium*. In the present discussion an attempt is being

made to present the differences between *Nematosporangium* (Schröter's version) and *Sphaerosporangium*.

The statements of the various investigators make it clear that the different members of *Nematosporangium* are distinguishable from those of *Pythium* by the absence of spherical or lemon-shaped prosporangia and conidia (FIG. 1, *a*, *b*). The nematoid or allantoid prosporangia of *Nematosporangium* often undergo elongation and assume vegetative growth which should not be confused with the true germination of conidia of members of the genus *Pythium*. In the matter of zoöspore production *Nematosporangium* and *Pythium* are alike only in the development as an outgrowth from the prosporangium of a vesicle or zoösporangium proper, in which the zoöspores are borne. Resemblances quite analogous to this may be found between the genera *Phytophthora*, *Albugo*, *Basidiophora*, *Sclerospora* and, in part, *Plasmopara*, where the stage of the germ sac (true zoösporangium or vesicle) has almost entirely been suppressed, that is, the mature zoöspores swarm directly out of the prosporangium; yet there is no question as to generic differences between these organisms.

The mycelium in *Nematosporangium* is very irregular with outgrowths of different shapes and sizes, whereas that of the majority of members of the genus *Pythium* is fairly uniform in shape, although it may vary to an appreciable extent in size. There are, however, certain new species of *Pythium*[1] that exhibit a close resemblance to the *Nematosporangium* type of mycelium. The mycelium of species of *Pythium* has never been observed by the writer to form bud-like outgrowths or plasmatoögoses[2] in the tissues of hosts, whereas that of *Nematosporangium* always does.

The oögonia and oöspores of the members of both genera are always spherical, except for irregularities in some of the oöspores developing inside the tissues of hosts. The surface of the oöspore wall of all the species of *Nematosporangium* so far studied is smooth, except for slight wrinkles that may be found on the oögonial membrane of those species not filling the oögonium,

[1] Described in a paper following on *Pythium*.

[2] Plasmatoögosis(es) from the Greek πλάσμα and ὄγκωσις, plasmatic outgrowths or the bud-like outgrowths of Butler (2).

whereas that of those of *Pythium* may be smooth, reticulate. or echinulate. The oöspore may or may not fill the oögonium in both *Pythium* and *Nematosporangium*. There is a considerable variation in the size of the oöspores of both genera under cultural and, to a considerable degree, under natural conditions, The great or small number of oöspores correlated with an early or late production inside the tissues of hosts is characteristic of many species of both genera and may be used for the identification of closely related species. The shape and size of the fertilization tube, its position in relation to the antheridium, and also the position of the antheridium in respect to the oögonium, the number of antheridia produced on the same hypha, and the number attached to an oögonium, constitute valuable characters for the identification of species.

The most outstanding differences between *Nematosporangium*, *Pythium*, and *Phytophthora* are in their zoöspore-producing organs. Those of *Nematosporangium* and *Pythium* are divided into three morphologically different parts, prosporangium, exit tube, and zoösporangium. The prosporangium serves as reservoir of the protoplasm destined for the development of zoöspores. The exit tube forming simultaneously with or slightly before the development of the zoösporangium separates the prosporangium from the zoösporangium and serves for the passage of the protoplasm from the former to the latter organ. The wall of the prosporangium is a continuation of the exterior wall of the hypha supporting this organ, whereas that of the zoösporangium is not, but constitutes a part of the so-called ectoplast of the prosporangium. The zoösporangium is of short duration; it emerges from the emission collar almost simultaneously with the flowing protoplasmic contents of the prosporangium and lasts until the zoöspores are completely formed and have escaped into the surrounding medium. The corresponding organs in *Phytophthora* vary widely from this. The three genera may be differentiated as follows:

Nematosporangium: Prosporangia (being morphologically identical with plasmatoögoses) are not well defined structures. They may be nematoid, allantoid, or rarely subspherical, intra- or extra-marginal; exit tube very long; zoösporangia spherical,

size variable; zoöspores few to many; conidia unknown (FIG. 1, *a*, *b* and *c*).

Pythium: Prosporangia well defined, pithoid,[3] spherical to ovoid, mostly extramatrical, rarely intramatrical; exit tube short; zoösporangia spherical, size variable; zoöspores few to many; pseudoconidia present in certain species (FIG. 1, *d* and *e*).

Phytophthora: Prosporangia well defined, not pithoid, lemon-shaped to spherical but without a prominent neck, mostly extramatrical of different sizes; zoösporangia developing within the walls of prosporangia; exit tube entirely lacking or rarely slightly developed; zoöspores few to many, pseudo- and euconidia present (FIG. 1, *f*, *g*, *h* and *i*).

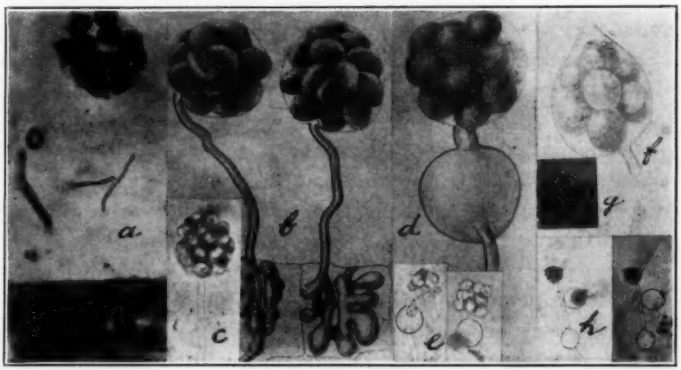


FIG. 1. *a*, zoösporangium of *Nematosporangium* sp. and prosporangium in the cell of the host (× 600); *b*, drawing of a zoösporangium of *Nematosporangium* sp.; *c*, zoösporangium of *Nematosporangium* sp. (× 300); *d*, drawing of a prosporangium and zoösporangium of *Pythium* sp.; *e*, two prosporangia with their zoösporangia of *Pythium* sp.; *f*, drawing of the prosporangium-zoösporangium of *Phytophthora* sp.; *g*, prosporangium-zoösporangium with zoöspores of *Phytophthora* sp.; *h*, prosporangium-zoösporangium discharging its zoöspores (× 300); *i*, two emptied prosporangia-zoösporangia and an undeveloped one (× 150).

The separation of *Nematosporangium* from *Pythium* and the creation of two independent genera, by Schröter, was not only wise, but was also a necessity for a better understanding of the morphological characters and physiological behavior of the vari-

[3] *Pithoid* from the Greek πιθώδης = jug-like, that is, spherical to oval with a well defined open neck at the top.

ous members of the two genera. Fischer (**7**), Butler (**2**), and other investigators have not approved of the division of *Pythium* into two independent genera, because of a character common to both genera: *viz.*, the development of a vesicle, or zoösporangium proper, into which the zoöspore or protoplasmic material is discharged by the prosporangium through a tube. It is rather unfortunate that the size, shape, and other characters of the prosporangium and exit tube in the two genera have been overlooked or characterized as unimportant.

Besides the morphological differences, there are physiological differences which point out that the members of the two genera stand out as two independent units. There is, doubtless, a certain relationship between *Nematosporangium* and *Pythium*, but not any greater than that existing between any two other genera of the same family.

THE GENUS NEMATOSPORANGIUM

This genus, then, as characterized above, is sharply differentiated from the other two genera of the family Pythiaceae. In differentiating species within the genus, one looks naturally first of all to morphological characteristics. These characters in closely related species, however, are not as prominent as cultural characters which have been used quite extensively for the differentiation of such species.

The morphology of the sexual organs constitutes a more reliable criterion for the differentiation of species than that of the asexual organs. The size of the asexual organs, namely, zoösporangia, depends on the size of the prosporangia. The latter organs vary considerably, as they may be composed of one or many lobes and thus contain either a small or a great volume of protoplasmic material which determines in turn the size of the zoösporangium and the number of zoöspores.

The prosporangia of *Nematosporangium* being, as mentioned before, morphologically identical with plasmatoögoses can not be differentiated from them before they produce zoösporangia. They may consist of a single morphologically undifferentiated hypha of few to many microns in length (nematoid) or of morphologically differentiated hyphae of diameter many times that

of the unmodified or original hypha, with few or many lobes filled with protoplasmic matter (allantoid). They produce during the development of zoösporangia an exit tube or discharge tube, ranging in length between 25 and 300 μ or possibly longer, which, after opening at the tip, permits the outward passage of the vesicle and protoplasmic matter. The period required for the flow of the protoplasmic matter from the prosporangium to the vesicle or zoösporangium varies considerably, ranging between 10 and 40 seconds and depending mainly on the volume of such matter.

The zoösporangia of *Nematosporangium* vary considerably in size and in the number of zoöspores, the latter numbering from 4 to 50 or possibly more. In certain species, they form very readily in the culture media or in water, and in others, very slowly. In the latter case it was found necessary to take the dead roots of hosts that had been recently inoculated and killed by the organisms in question, place them in water and watch for the development of zoösporangia. The only species that have been observed to produce zoösporangia readily, when the aërial mycelium of the colony is used, are *Nematosporangium aphanidermatum* and *N. Butleri* (**13**). The others produce zoösporangia readily, only if the diseased tissue of the root of the host is used, as far as the author's observations have gone. The development of zoöspores within the zoösporangium requires from 15 to 20 minutes. The prosporangium first produces a discharge tube, which may measure from 20 μ to 300 μ in length. Then, at the tip of the tube appears the zoösporangium as a bubble-like sphere, first small, but increasing gradually until it reaches its maximum size. During the enlargement of the zoosporangium the protoplasm is continuously flowing in as a viscous mass. The latter process may last from few to many minutes and then starts the differentiation and development of zoöspores (FIGS. 4 to 12). The swarm stage lasts from 2 to 30 minutes and possibly longer, depending on the temperature of the environment. The zoöspores are reniform and biciliate in all the different species.

Plasmatoögoses are of great importance in the characterization of species. Plasmatoögoses may either group together and form

few large or many small tufts (intramatrical or extramatrical), or may be produced individually without the formation of aggregates. The size of such aggregates varies and is characteristic of certain varieties. Plasmatoögoses are also known by the name prosporangia. It is true that plasmatoögoses and prosporangia are morphologically identical, but until the latter produce zoösporangia one does not know definitely whether they are prosporangia or only protoplasmic accumulations that may produce a vegetative growth. Plasmatoögoses are analogous to the conidia of certain species of *Pythium* which may either become prosporangia if they produce zoösporangia or remain and germinate vegetatively and in the latter case be true conidia. The term prosporangia is inappropriate for these structures for the reason above stated.

On the basis of the morphology of the sexual reproductive organs, *Nematosporangium* may be divided into two sections, namely, *Polyandra* and *Oligandra*, the former including those members having many antheridia, usually 1 to 25, in relation to one oögonium, and the latter, those having few, usually one or two, in relation to one oögonium.

All of the members of the section *Polyandra* can be placed in three distinct groups or subsections on the basis of the time required for sexual reproduction, either in culture media or in the tissues of hosts. The members of the section *Oligandra* are placed in two subsections on the basis of their behavior in the development of zoösporangia. The subsections of the section *Polyandra* are as follows: (1) *Bradyspora* [4] including those members requiring very long time (5 to 25 days) and highly suitable culture media containing relatively high concentrations of nutrient substances; (2) *Hemibradyspora* those requiring a relatively short time (2 to 4 days) and highly suitable culture media; and (3) *Tachyspora* [5] those requiring a short time (1 to 3 days) in a great variety of culture media, even those containing relatively low concentrations of nutrient substances. The subsections of *Oligandra* are (1) *Plethorocomba* [6] and (2) *Oligocomba*.[7] The

[4] *Bradyspora* = slowly-produced spores, from the Greek βραδὺς = slow.

[5] *Tachyspora* = rapidly-produced spores, from the Greek ταχὺς = rapid.

[6] *Plethorocomba* = abundance of knots (referring to plasmatoögoses on the aërial hyphae), from the Greek πληθώρη = abundance + κόμβος = knot.

[7] *Oligocomba* = few knots; from the Greek ὀλίγος = few + κόμβος = knot.

former includes those members with many plasmatoögoses on their aërial hyphae, developing zoösporangia readily, and, the latter, those with very few plasmatoögoses developing zoösporangia rarely.

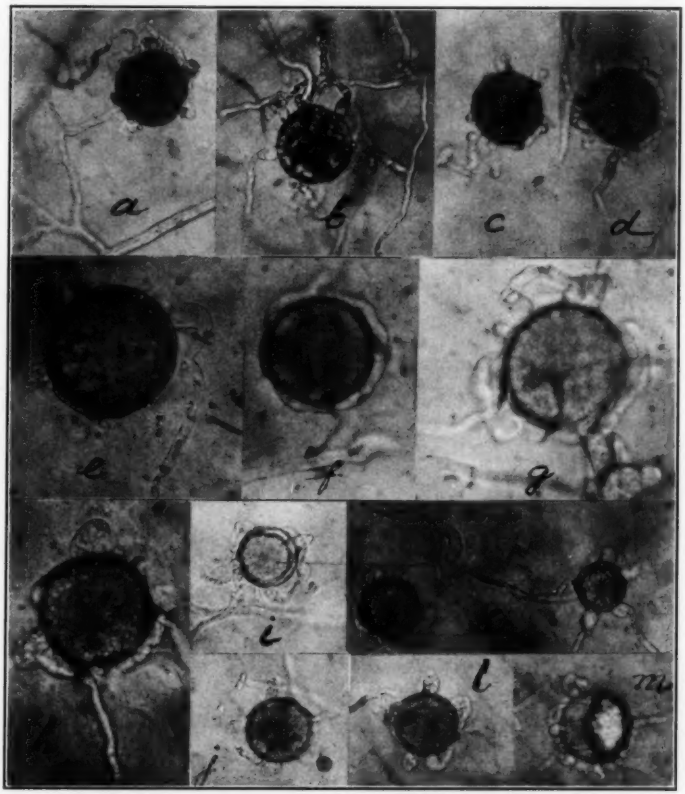


FIG. 2. *a, b, c, d, e, g, h, i, j, k, l,* oöspores fertilized by single and compound antheridia, that is, antheridia produced by one per hypha or many per hypha produced on short branches arising from a common hypha; *f,* oögonium surrounded by a hypha previous to the production of antheridia; *m,* oöspore showing the multi-branching of the antheridial hypha and the four antheridia produced on its branches.

The members of the subsection *Bradyspora* produce oöspores rarely and few in number within the tissues of hosts; those of

the second subsection produce them occasionally, but in greater numbers in tissues containing a sufficient and suitable food supply and those of the third subsection produce them in the tissues of practically all the hosts so far studied. Members of the subsections *Bradyspora* and a few of *Hemibradyspora*, besides the long time they require for sexual reproduction, have their reproduction preceded by the formation of plasmatoögoses. These organs (FIG. 3, *a*, *b* and *c*), being filled with protoplasmic matter, serve possibly as storage organs in the subsections *Bradyspora* and *Hemibradyspora*, and thus make possible the wasteful process of sexual reproduction.

Plasmatoögoses of smaller sizes occur in the colonies of all species of the subsection *Tachyspora*. In this subsection, however, they either develop simultaneously with the oöspores or later, thus exercising no influence on the formation of oöspores. Such protoplasmic accumulations, called by many, prosporangia, may serve three purposes: (1) the development of zoösporangia, (2) development of oöspores and (3) continuation as storage hyphae, functioning as chlamydospores.

Some members of the subsection *Plethorocomba* produce oöspores very readily and mostly on the surface of the substrata and aërial hyphae and others slowly. For example, *N. aphanidermatum* produces oöspores very readily, whereas *N. Butleri* produces them slowly. *N. Indigoferae* of the subsection *Oligocomba* produces oöspores extremely abundantly intra- and extramatrically and intra- and extra-cellularly. The oöspores of all the members of subsections *Plethorocomba* and *Oligocomba* are aplerotic.[8]

The antheridia in the various species of *Nematosporangium* vary considerably in size, shape and number per hypha (FIG. 2, *a*, *b* and *e*). The shape, in practically all of the species of *Polyandra*, is clavate and the length of the supporting stalk relatively long, although it varies considerably in certain species. The shape in the members of *Oligandra* is doliform and the length of the supporting stalk relatively short and in many cases almost lacking. The size of the antheridia of the different species varies

[8] Plerotic type = filling the oögonium, from the Greek πληρωτικός; aplerotic = not filling.

but slightly within the entire genus. The number of antheridia that may be borne laterally on a single hypha also varies. There are hyphae bearing many antheridia laterally which act as a single unit in the process of fertilization. Such hyphae usually encircle the oögonium and all of the antheridia become attached (FIG. 2, *d*, *f* and *g*). It is extremely difficult if not impossible to differentiate between the oögonial and antheridial hyphae pre-

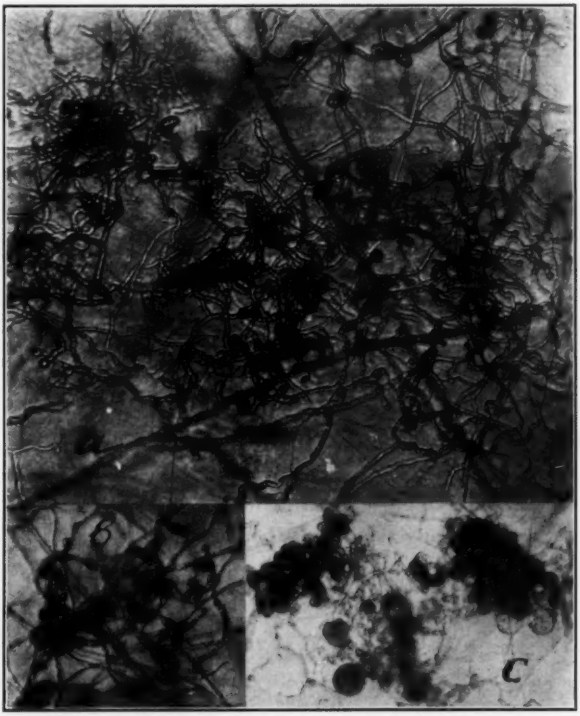


FIG. 3. *a*, plasmatoögoses which may produce zoösporangia or serve as storage cells; *b*, *c*, plasmatoögoses: *b*, young, and *c*, old, the latter producing oögonia.

vious to the formation of such organs. The antheridia of *Nematosporangium* may be borne either on the same hypha bearing the oögonium or on separate hyphae. It seems that oögonia

influence the development of antheridia on nearby hyphae or on the same hypha either by endogenic or exogenic secretions or other such biochemical stimuli. That the reverse is not true is evidenced by the fact that the formation of oögonia always precedes that of antheridia.

The formation of oögonia in *Nematosporangium* depends on the quality and quantity of the available nutrients of culture media. Their size varies in the same proportion as oöspores. The number of antheridia, in relation to a single oögonium in the section *Oligandra*, including such species as *N. aphanidermatum* and *N. Butleri*, is limited to very few, 1 to 4, whereas in *Polyandra* it may vary from 1 to 12 and possibly more. Drechsler (**5**) reported as many as 25 in *Pythium arrhenomanes* Drechsler.

The oöspores of all species of *Nematosporangium* are morphologically alike, being smooth, spherical to subspherical, and surrounded by a wall varying in thickness between 1.2 and 2.0 μ.

Those of the section *Polyandra* are relatively large, averaging 30 $\pm$ 5 μ in diameter in comparison to those of *Oligandra* which average 20 $\pm$ 5 μ. The oöspores of all or most of the members of the section *Polyandra* are of the plerotic type whereas those of the *Oligandra* are of the aplerotic type. All of the members of *Oligandra* reproduce sexually very readily in comparison to those of the *Polyandra* (excepting *Tachyspora*). The oöspores of practically all species of *Polyandra* except some oöspores of *N. epiphanosporon* are produced in the substratum or on its surface, whereas those of *Oligandra* are mostly produced on the aërial mycelium.

NUTRITIONAL REQUIREMENTS OF NEMATOSPORANGIUM

The macroscopic or cultural characters of the organisms discussed in this paper have been observed to depend on the nutritional value and physicochemical properties of the various culture media. Appropriate culture media should be used as much as possible for the identification and standardization of these organisms. During these studies a very great number of culture media were tested and only those that favored the normal development, that is, the sexual and asexual reproductive processes of these various organisms, were selected.

The nutritional requirements of the various species of *Nematosporangium* for normal growth and sexual reproduction are exacting. There are very few food substances which possess properties for stimulating sexual reproduction in the various members of *Nematosporangium*. Sexual reproduction, being a very wasteful process, requires appreciable quantities of food substances that are rich in readily available nitrogenous compounds, fats, and sugars—substances from which protoplasm can be readily produced. Such substances as the seeds of plants and other parts of the fruit which are rich in such suitable food substances, as mentioned, make the best culture media for the growth of this group of organisms. Not all seeds but only those of a relatively small number of plants are suitable for this purpose. Chemical differences in the composition of the seeds of different plants are doubtless responsible for the suitability or nonsuitability of such seeds for culture media.

Synthetic culture media are not suitable for the sexual reproduction of some of these organisms.

CULTURE MEDIA

Various synthetic as well as natural culture media have been tested but only the latter gave good results. In spite of the variability within a species of the chemical composition of the pericarp of the fruit, there is little or no variability in the chemical composition of the seed. Seeds offer, therefore, the greatest degree of reliability for comparative studies of this type. For the preparation of the different culture media employed in these studies decoctions of the various vegetable substances were prepared. Such decoctions were then mixed with agar-agar for the preparation of solid media in the proportion of 1000 cc. of decoction to 17.5 grams of agar-agar.

The natural culture media used were as follows:

A. Cornmeal agar (*Zea Mays*). This was a preparation obtained from the Digestive Ferments Company.

B. Quaker Oats agar (*Avena sativa*). This was prepared by boiling 50 grams of Quaker Oats in 1000 cc. of water for 30 minutes. The mixture was filtered through cotton.

C. Flaxseed agar (*Cannabis sativa*). About 25 grams of

seeds are boiled for 30 minutes in 500 cc. of water and then strained through cotton. The residue is mixed once more with 500 cc. of water boiled for ten minutes and then strained. The first and second liquid portions are united.

D. Hemp seed and Quaker Oats agar. This is prepared by mixing 500 cc. of flaxseed decoction and 500 cc. of Quaker Oats decoction.

E. Cocoanut agar (*Cocos nucifera*). Only fresh, ripe cocoanut was used for the preparation of culture media. Two hundred grams of the endosperm together with the milk and 1000 cc. of water are boiled for one hour and then filtered through cotton.

F. Melon-seed agar (*Cucumis Melo* var. honeydew). Twenty-five to 30 grams of melon seeds are ground up in a meat grinder, mixed with 1000 cc. of water and boiled for one hour. The mixture is filtered through cotton.

G. Watermelon-seed agar (*Cucumis Citrullus*). The preparation is identical with that of the melon-seed agar.

H. Pumpkin-seed agar (*Cucurbita Pepo*). The preparation is identical with that of the melon-seed agar.

I. Avocado agar (*Persea gratissima*). About 200 grams of the pericarp removed from the peel, mixed with 1000 cc. of water and boiled for two hours. The mixture is filtered through cotton.

J. Papaya agar (*Carica Papaya*). Only the ripe fruit of *Carica Papaya* is suitable for the preparation of media. One thousand grams of the peeled fruit is ground finely by means of a meat grinder, heated to boiling with 500 cc. of tap water for ten minutes, and then strained through cotton. The liquid is set aside and the solid residue mixed once more with 500 cc. of water, boiled for ten minutes and again strained. The first and second liquid portions are united.

K. Watermelon agar (*Cucumis Citrullus*). Both seeds and flesh of the watermelon were used for the preparation of this culture medium. The seeds were separated from the flesh and a decoction of them was prepared as described above under *G.* The juice extracted from a 6-pound watermelon by means of a fruit press (about one liter) was boiled for 20 minutes until the pigment coagulated and was then filtered through coarse filter

paper. The filtrate, a pale liquid, was mixed with an equal volume of the seed decoction.

L. Melon seed, flaxseed, and dextrose agar. Equal volumes of decoctions *C* and *F* are mixed. To 1000 cc. of the mixture 5 grams of dextrose is added.

A great variety of other substances have been used for the preparation of culture media in connection with these studies, such as potato (*Solanum tuberosum*), carrot (*Daucus Carota*), sweet potato (*Ipomoea Batatas*), bean sprouts (*Phaseolus Soja*) and combinations such as cornmeal, papaya, etc., but without any additional advantages.

The papaya culture media proved to be the best for reproduction and growth. It is recommended wherever the papaya fruit is available. The next best is the seeds of honeydew and watermelon. The pumpkin-seeds were not as satisfactory as the melon seeds. The chemical differences existing in these seeds, as given by Wehmer (**15**), cannot be used for ascertaining such properties as those required for the sexual reproduction of these organisms. The results obtained indicate that the nitrogenous and lipoid compounds must exist in a relatively high concentration in proportion to the carbohydrate substances in order to bring about normal sexual reproduction.

Besides the general requirements for sexual reproduction by the majority of species, there are certain species that refuse to reproduce except on few favorable media. This high specialization which is indicative of the influence of certain chemical compounds on the sexual reproduction of species of *Nematosporangium* emphasizes the importance of the substratum in the development of morphological characters and its bearing on the taxonomy of these organisms.

The behavior of these organisms in different culture media is analogous to that of bacteria. The development of morphological characters in the species of *Nematosporangium* may be compared with the biochemical changes resulting in the substrata of different species of bacteria. It is very difficult, if not impossible, to identify the various species of *Nematosporangium* on simply morphological differences of their various organs without using culture media that have been tested and proven to give variations in the growth and reproduction of these organisms.

TECHNIQUE

The technique employed in studying the different organisms consisted in growing them on the various substrata mentioned, contained in Petri dishes. They were examined at 6- or 12-hour intervals by means of a compound microscope, using a 16 mm. objective and × 15 eyepiece, the Petri dishes placed on the stage closed and with their bottom sides up. By means of such precautions the contamination of cultures was reduced to minimum. Certain optical difficulties were met with in pigmented and turbid culture media. All these difficulties were finally overcome by using a very strong source of light (a 400-watt lamp). The magnification, × 150, given by combining a 16 mm. objective with a × 15 eyepiece was found sufficient and satisfactory for this type of work.

It has been observed that all the different kinds of culture media, mentioned above, form some precipitate, consisting mostly of coagulated albumins or other proteins, during their sterilization in the autoclave. Such precipitates should neither be filtered out nor left at the bottom of the test tube when the contents of the latter are poured into Petri dishes, but should be shaken well with the clear liquid and poured together. They have been observed to be indispensable for the initial development of oögonia, especially with members of the subsection *Hemibradyspora*. Comparative studies on species of *Nematosporangium* should be conducted, with as many replications of cultures as possible, to detect variation induced by minor external factors. The writer found that five Petri-dish cultures for each organism at one time on any single test were the fewest that could have been used.

The results obtained on sexual reproduction of different species with the various culture media above mentioned are recorded in Table I.

KEY TO THE SPECIES OF NEMATOSPORANGIUM [9]

A. Antheridia, 1 to 25, in relation to a single oögonium, narrow, clavate, and agchylolaimic,[10] mostly on long stalks; oöspores, plerotic mostly; section: *Polyandra*.

[9] This key is more descriptive than necessary for the purpose of pointing out most of the outstanding morphological and cultural characters of each organism.

[10] agchylolaimic = crooknecked, from the Greek ἀγκύλος = crook and λαιμός = neck.

TABLE I

PRODUCTION OF OÖSPORES BY DIFFERENT SPECIES OF *Nematosporangium* IN VARIOUS CULTURE MEDIA

Organisms[1]	Oöspore production in days[2]											
	Culture media											
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*
Polyandra												
N. arrhenomanes	−	−	−	−	+5	−	−	−	−	+15 20	+7	+10
N. " var. *hawaiiensis*	−	−	+20	−	−	−	−	−	−	+(?)	−	−
N. " Branstetter's	−	−	−	−	−	−	−	−	−	+20	+7	−(?)
N. spaniogamon	−	−	−	−	−	+2	+2	−	−	+2	+2	+3
N. hyphalosticton	−	−	−	−	−	+4	+5	+2	−	+10	−	−
N. polyandron	−	−	−	+3	−	+3	+3	−	+4	+2	+2	+2
N. thysanohyphalon	−	+	−	+3	−	−	+2	−	+3	+4	+3	+2
N. rhizophthoron	−(?)	+	+	+2	+	+2	+2	+2	+2	+3	−	+2
N. leucosticton	+	+1	+	+1	+1	+	+1	+1	+	+	+2	+1
N. leiohyphon	+	+	+	+1	+	+	+1	+1	+1	+	+2	+2
N. epiphanosporon	−(?)	+1	+	+1	+1	+1	+1	+1	+2	+2	+2	+2
Oligandra												
N. aphanidermatum	+	+	+	+	+	+	+1	+1	+	+2	+2	+2
N. Butleri	−	−	+	+	−	−	+	−	−	+	−	+4
N. Indigoferae	−	−	+	−	−	−	+2	−	−	+	+	+4

[1] The species listed here are described later in this paper.

[2] Production of oöspores indicated by + and nonproduction by − signs. Numbers have been inserted after + signs in some cases indicating the number of days required for their production.

B. Organisms reproducing sexually only in a limited variety of culture media and in the tissues of hosts rarely and after a long time; oöspores very few in culture media and tissues of hosts; produced near plasmatoögoses; plasmatoögoses small submerged in the substrata; subsection: *Bradyspora.*

C. Aerial mycelium well-developed especially in culture media containing sugars; branching hyphae relatively straight.

D. Oöspores produced in 5 to 15 days on culture media E, J and K. *N. arrhenomanes*.....(1)

DD. Oöspores produced in 10 to 15 days on culture media C and J. *N. arrhenomanes* var. *hawaiiensis*.....(2)

CC. Aerial mycelium slightly cespitose; branching hyphae zigzagged; oöspores produced in 5 to 20 days on culture media J and K. *N. arrhenomanes* var. Branstetter.....(3)

BB. Organisms reproducing sexually in 2 to 5 days on highly suitable culture media and on less suitable culture media in 7 to 25 days or never; oöspores produced mostly from plasmatoögoses; subsection: *Hemibradyspora.*

C. Oöspores produced rarely or never in the tissues of hosts, from few to many on culture media; plasmatoögoses submerged in the substratum, not in aggregates; aërial mycelium slightly to moderately developed; oöspores mostly abortive, produced in 1 to 3 days on culture media F, G, J, K and L; *N. spaniogamon*.....(4)

CC. Oöspores many developing independently or from plasmatoögoses on suitable culture media; few in the tissues of hosts; plasmatoögoses (on *Carica Papaya* media) grouping in aggregates and protruding slightly above substratum; aërial mycelium well-developed, mostly marginal.

D. Plasmatoögoses (on *Carica Papaya*) small, 0.5 to 2 mm., but numerous; oöspores produced in 3 to 15 days, on F, G, H and J culture media; *N. hyphalosticton*.....(5)

DD. Plasmatoögoses (on *Carica Papaya* media) few but large, 2 to 7 mm. in diameter; aërial mycelium mostly marginal; oöspores produced in 1 to 2 days, on D, F, G, I, J, K and L, and on less suitable media after 10 to 15 days from plasmatoögoses; *N. polyandron*.....(6)

DDD. Plasmatoögoses (on *Carica Papaya* media) with some aërial mycelium, few and large; aërial mycelium over entire colony; oöspores produced in 1 to 3 days on B, D, G, I, J, K or L, never or seldom produced from plasmatoögoses; *N. thysanohyphalon*.....(7)

BBB. Sexual reproduction requiring from 1 to 3 days on all culture media; exception, *N. rhizophthoron* in media A and K; oöspores in great numbers intra- and extra-matrical in culture media and in tissues of hosts; plasmatoögoses small not in aggregates and produced in or on the surface of the substratum; subsection: *Tachyspora.*

C. Oöspores intramatrical, mostly fertile and mostly submerged in the substratum; plasmatoögoses (on *Carica Papaya* media)

submerged in the substratum; aërial mycelium well-developed in culture media containing sugars; *N. rhizophthoron*. . . . (8)

CC. Oöspores mostly intramatrical one-third to one-half abortive; plasmatoögoses (on *Carica Papaya* media) protruding above the surface of the substratum as whitish specks; aërial mycelium moderately developed, mostly marginal; *N. leucosticton*. . . . . (9)

CCC. Oöspores intramatrical and mostly abortive; plasmatoögoses few, embedded in the substratum; aërial mycelium lacking in all culture media except E, K and L; *N. leiohyphon*. . (10)

CCCC. Oöspores extramatrical or mostly on aërial mycelium, nine-tenths abortive; plasmatoögoses very few, small and embedded in substratum; aërial mycelium well-developed and may cover entire colony or margins; *N. epiphanosporon*. . . (11)

AA. Antheridia, 1 to 2 and rarely 3 to 4, in relation to a single oögonium; broad barrel-shaped, slightly clavate, few with long and mostly with very short stalks, or in some cases, the stalks entirely lacking; oöspores not filling oögonium; section: *Oligandra*.

B. Organisms with most plasmatoögoses developing zoösporangia, reproducing asexually by means of zoöspores very readily in water, grown either on a great variety of culture media or in the tissues of hosts; subsection: *Plethorocomba*.

C. Oöspores numerous produced mostly on aërial mycelium in 1 to a few days, on all culture media; plasmatoögoses numerous, produced in the hyphae of aërial mycelium not in aggregates; aërial mycelium profuse in most culture media especially those containing sugars; hyphae, 5 to 10 μ in diameter, producing many branches at the tips; zoösporangia developing in a few minutes; *N. aphanidermatum*. . . . . (12)

CC. Oöspores not very numerous, produced mostly on aërial mycelium, in 3 to 5 days, on C, D, F, G, J and L; plasmatoögoses not very numerous; aërial mycelium moderately developed.

D. Hyphae 5 to 10 μ in diameter, producing many branches at tips; zoösporangia developing in a few to many minutes; *N. aphanidermatum* var. *hawaiiensis*.

DD. Hyphae, 5 to 10 μ in diameter, thysanoid at tips; zoösporangia developing in a few hours; *N. Butleri*.

BB. Organisms with very few atypical plasmatoögoses produced in liquid and solid favorable culture media, but not in the tissues of hosts; seldom developing into zoösporangia; subsection: *Oligocomba*.

Oöspores numerous on aërial and submerged mycelium; plasmatoögoses on mycelium relatively few; not very prominent; aërial mycelium moderately developed; hyphae, 3 to 5 μ in diameter, with little branching; zoösporangia developing very seldom with few zoöspores; oögonial stalk bending towards antheridium; *N. Indigoferae*.

DESCRIPTION OF SPECIES

(1) **N. arrhenomanes** (Drechsler) comb. nov. described by Drechsler (**5**).

(2) *N. arrhenomanes* var. **hawaiiensis** var. nov. (FIG. 4).

(*Pythium arrhenomanes* Drechsler, Phytopathology **18:** 873–875, 1928.)

Mycelium intra- and extracellular, in culture media exhibiting a profuse aërial development over the entire colony in young cultures; hyphae irregular, 3 to 6 μ in diameter (average 3 μ); plasmatoögoses as individual units and as aggregates, the latter forming occasionally in old cultures and the former being distributed uniformly in the substratum, individual plasmatoögoses 100 to 400 μ, aggregates 1 to 15 mm., those produced in culture media very seldom developing into prosporangia, abundant in the tissues of hosts in both young and old infections; zoösporangia produced readily from prosporangia under proper environmental conditions, 25 to 45 μ in diameter, containing from 4 to 50 biciliate reniform zoöspores; zoöspores formed in 15 to 20 minutes in the zoösporangium, motile for 10 to 30 minutes or possibly longer, then rounding up as subspherical bodies about 10 μ in diameter which may germinate in a few hours by one germ tube measuring almost 3 μ in diameter; oögonia subspherical, terminal, very few in cultures of three or more weeks old, mostly near the plasmatoögoses, extremely few elsewhere, 20 to 34 μ in diameter (average 28 μ); antheridia agchylolaimic 5 to 8 μ in diameter in the distal expanded portion, 10 to 20 μ in length along curved axis from apex to basal septum, the proximal part more gradually tapering toward delimiting septum to diameter of supporting filament, numerous, from 1 to 15 or possibly more often visible in relation to one oögonium, borne terminally and (quite often) laterally on branches arising from the same hypha, the latter surrounding the oögonium and bearing 2 to 12 antheridia; oöspores subspherical, yellowish mostly, plerotic, about 25 μ in diameter, and surrounded by a wall about 1.5 μ in thickness, germinating in a few weeks giving rise to vegetative hyphae which may or may not produce prosporangia depending on environmental conditions, rarely occurring in the tissues of hosts and then only in old infections. (Culture media, such as a decoction of the seeds of *Cannabis sativa* or the juice of the ripe fruits of *Carica Papaya*, are best suited for their development.)

It was obtained from the diseased roots of *Ananas sativus* grown on the island of Oahu of the Hawaiian Archipelago. It

is a root parasite of *Ananas sativus*, *Saccharum officinarum* var. H 109, and Lahaina, *Zea Mays*, *Triticum vulgare*, *Panicum barbinode*, *Musa sapiente*, *Cajanus indicus* var. New Era, *Phaseolus aureus*, *Solanum tuberosum*, and *Ipomoea Batatas*.

(3) *N. arrhenomanes* var. Branstetter (1).

(4) **N. spaniogamon** sp. nov. (FIG. 5).

Mycelium intra- and extracellular, in culture media slightly cespitose, exhibiting a moderate aërial development; hyphae irregular, 3 to 6 μ in diameter (average 4.5 μ); plasmatoögoses (on *Carica Papaya* media) as individual units, never as aggregates forming large colonies, distributed more or less uniformly in the substratum, 100 to 1000 μ, individual hyphae, 10 to 20 μ, produced in culture media and in the tissues of hosts; zoösporangia produced readily in hanging drop cultures from prosporangia under favorable environmental conditions, 25 to 40 μ in diameter containing from 4 to 50 biciliate reniform zoöspores; zoöspores formed in 15 to 20 minutes; in the sporangium, motile for 10 to 30 minutes and possible longer, depending on temperature and optimum condition of the surrounding solution, rounding up as subspherical bodies about 12 μ in diameter which may germinate in a few hours by one or sometimes two germ tubes 2.5 to 3.0 μ in diameter; oögonia subspherical, terminal, produced in 2 to 4 days, in highly suitable substrata, many proliferating and abortive, 20 to 30 μ in diameter (average 25 μ), production mostly limited to a single crop; antheridia developing very seldom, agchylolaimic, clavate, and mostly narrow, fertilizing only 2 to 10 per cent of the oögonia produced in the substratum, 1 to 8 in relation to a single oögonium, agchylolaimic, width 5 to 8 μ, length 8 to 12 μ along curved axis from apex to basal septum, variable in size and shape; oöspores subspherical, yellowish, mostly plerotic, about 25 μ in diameter and surrounded by a wall 1.5 μ in thickness, germinating in a few days or weeks giving rise to vegetative hypha which may or may not produce prosporangia, never observed in the tissues of hosts, but produced in culture media prepared from melon seeds, watermelon seeds, papaya juice, etc.

It was obtained from the diseased roots of *Ananas sativus* grown on the island of Oahu of the Hawaiian Archipelago. It is an aggressive root parasite of *Ananas sativus*, *Saccharum officinarum* var. H 109 and *Lahaina*, *Zea Mays*, *Triticum vulgare*, *Panicum barbinode* and a weak parasite of *Commelina nudi-*

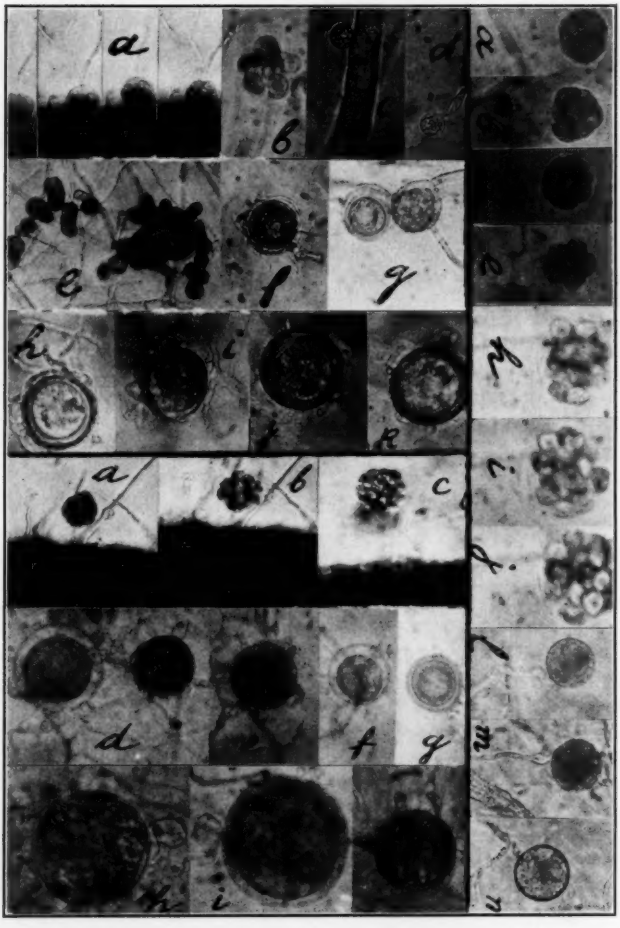


FIG. 4. (right) *N. arrhenomanes* var. *hawaiiensis*. *a*, *b*, *c*, *d*, *e*, development of zoösporangia (× 300); *h*, *i*, *j*, development of the zoösporangia (× 600); *l*, *m*, *n*, oöspores (× 300); (upper left) *N. hyphalosticton*. *a*, zoösporangia (× 150); *b*, zoösporangium (× 300); *c*, zoöspore entering a root hair; *d*, germinating zoöspore (× 300); *e*, plasmatoögoses in water; *f*, *g*, oöspores (× 300); *h*, *i*, *j*, *k*, oöspores (× 600); (lower left) *N. thysanohyphalon*. *a*, *b*, *c*, zoösporangia (× 150); *d*, *e*, *f*, *g*, *j*, oöspores (× 300); *h*, *i*, oöspores (× 600).

flora, Phaseolus aureus, Vicia faba, Solanum tuberosum and *Ipomoea Batatas.*

(5) **N. hyphalosticton** sp. nov. (FIG. 4).

Mycelium intra- and extracellular, in most culture media exhibiting moderate aërial development especially at the margins and occasionally center of the colony; hyphae irregular, 3 to 6 μ in diameter; plasmatoögoses (on *Carica Papaya* culture media) in many small aggregates 0.5 to 3 mm. in diameter, distributed either sporadically or cycladically on the substratum, developing either into oöspores or prosporangia, abundant in both young and old infections in the tissues of hosts; zoösporangia produced readily when infected tissues of hosts are placed in water, 25 to 45 μ in diameter, containing 4 to 50 biciliate reniform zoöspores; zoöspores formed in 15 to 20 minutes in the zoösporangium, motile for 10 to 30 minutes or possibly longer, rounding up as subspherical bodies about 10 μ in diameter which may germinate a few hours later by one germ tube 2.5 to 3.0 μ in diameter; oögonia subspherical, terminal, relatively abundant on suitable culture media, 28 to 38 μ in diameter, produced either on the laterals of ordinary hyphae in 3 to 4 days, or on those of plasmatoögoses in 2 to 3 weeks; antheridia agchylolaimic, width 5 to 7 μ, length 10 to 17 μ, along curved axis from apex to basal septum, the proximal part more gradually tapering toward delimiting septum to diameter of supporting filament, numerous, from 3 to 15 and possibly more often visible in relation to 1 oögonium, terminal and (quite often) lateral, 2 to 12, on very short branches of the same hypha, the latter surrounding the oögonium; oöspores spherical to subspherical, yellowish, mostly plerotic 32 μ in diameter and surrounded by a wall about 1.5 to 2.0 μ in thickness, produced in 3 to 4 weeks within or close to the area occupied by plasmatoögoses and only after the formation of the latter, germinating in a few days or weeks by one or (very seldom) two hyphae which may produce prosporangia immediately if environmental conditions are very suitable, rarely occurring in the tissues of hosts and then only in very old infections, produced on culture media prepared with melon seeds, watermelon seeds, and papaya juice.

It was obtained from the diseased roots of *Ananas sativus* grown on the islands of Oahu, Maui and Molokai of the Hawaiian Archipelago. It is a very aggressive root parasite of *Ananas sativus, Saccharum officinarum* var. H 109 and *Lahaina, Zea Mays, Triticum vulgare, Panicum barbinode* and a weak parasite

of *Musa sapiente*, *Cajanus indicus* var. New Era, *Phaseolus aureus*, *Solanum tuberosum* and *Ipomoea Batatas*.

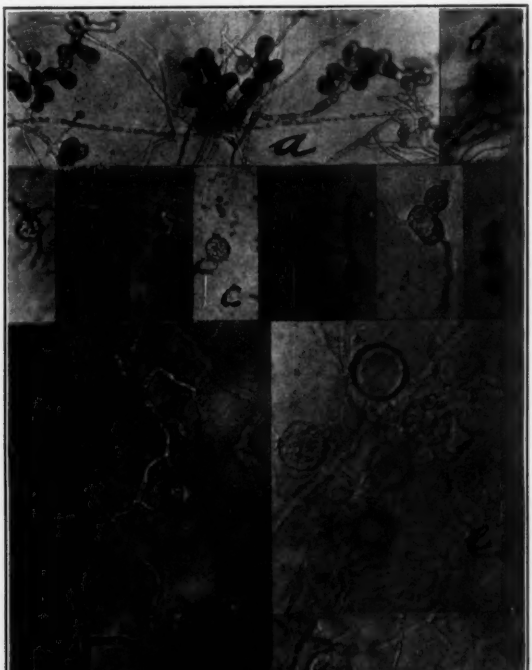


FIG. 5. *N. spaniogamon*. *a*, plasmatoögoses in water (× 300); *b*, zoösporangium (× 150); *c*, zoöspores (× 300); *d*, oöspore and undeveloped oögonia; *e*, abortive oögonia; *f*, abortive oöspore.

(6) **N. polyandron** sp. nov. (FIG. 6).

Mycelium intra- and extracellular, in culture media exhibiting moderate aërial development at the margins of the colony; hyphae irregular, 3 to 6 μ in diameter (average 4 μ); plasmatoögoses (on *Carica Papaya* culture media) in large aggregates 3 to 15 mm., few to many in cultures 3 to 4 weeks old, individual units 100 to 400 μ and individual hyphae from 10 to 25 μ, abundant in the tissues of hosts of both young and old infections; zoöspo-

rangia produced readily from prosporangia under proper environmental conditions, 25 to 45 μ, containing 4 to 50 biciliate reniform zoöspores; zoöspores formed in 15 to 20 minutes, motile for 10 to 30 minutes or possibly longer, then rounding up as subspherical bodies about 10 μ in diameter which germinate in a few hours by one germ tube 2.5 to 3.0 μ in diameter; oögonia subspherical, terminal, 28 to 38 μ in diameter (average 33 μ); produced in cultures 3 to 4 weeks old, in great numbers near or within the area occupied by plasmatoögoses; antheridia agchylolaimic, 5 to 7 μ in diameter in the distal expanded portion and 10 to 17 μ in length along curved axis from apex to basal septum, the rounded apical end making narrow contact with oögonium about a short fertilization tube that measures approximately 2.5 μ in diameter, the proximal part more gradually tapering toward delimiting septum, to diameter of supporting filament, numerous, from 1 to 15 or possibly more often visible in relation to an oögonium, terminal and (quite often) lateral on very short branches arising from single hypha, the latter surrounding the oögonium and bearing 2 to 12 antheridia; oöspores spherical to subspherical, yellowish, mostly plerotic, produced between plasmatoögoses in 3 to 4 weeks old cultures, about 32 μ in diameter, wall 1.5 to 2.0 μ thick, germinating in a few days or weeks by one or very seldom two hyphae which may produce prosporangia immediately if environmental conditions are very suitable, rarely occurring in the tissues of hosts and then only in very old infections, in culture media (hempseeds, melon seeds, watermelon seeds, avocado, papaya, etc.) produced in 2 to 4 days.

It was obtained from the diseased roots of *Ananas sativus* grown on the islands of Oahu, Maui and Molokai of the Hawaiian Archipelago. It is a very aggressive root parasite of *Ananas sativus*, *Saccharum officinarum* var. H 109 and *Lahaina*, *Zea Mays*, *Triticum vulgare*, *Panicum barbinode* and a weak parasite of *Musa sapiente*, *Cajanus indicus* var. New Era, *Phaseolus aureus*, *Solanum tuberosum* and *Ipomoea Batatas*.

(7) **N. thysanohyphalon** sp. nov. (FIG. 4).

Mycelium intra- and extracellular, in culture media exhibiting a profuse aërial development at the margins of the colony; hyphae irregular, 3 to 6 μ in diameter (average 4 μ); plasmatoögoses in large aggregates, 3 to 13 mm., few in number and mostly located at the center of the colony with small amount of aërial mycelium, forming in one week old cultures or slightly older; individual plasmatoögoses measuring from 100 to 400 μ

and their hyphae 10 to 20 μ; occurring abundantly in the tissues of hosts mostly completely filling the cells of hosts; zoösporangia produced readily from prosporangia under proper environmental conditions from infected tissues of hosts, 25 to 45 μ in diameter and containing from 4 to 50 biciliate reniform zoöspores; zoöspores formed in 15 to 20 minutes in the zoösporangium, motile for 10 to 30 minutes or possibly longer, then rounding as sub-

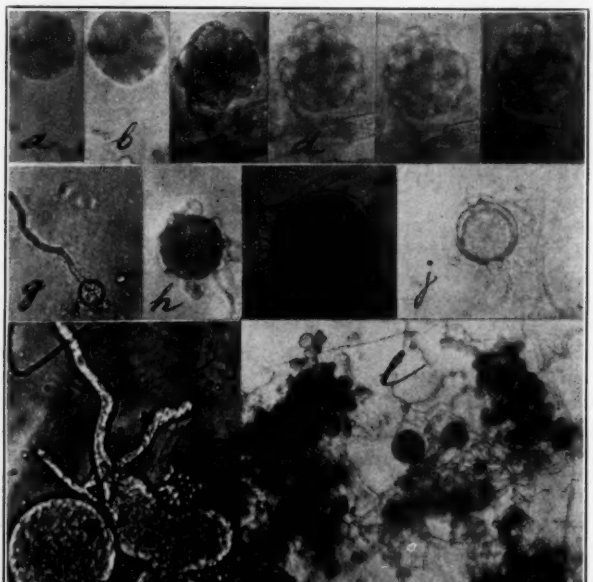


FIG. 6. *N. polyandron*. *a, b, c, d, e, f,* development of the zoösporangium (× 300); *g,* zoöspore (× 300); *h, j,* oöspores (× 300); *i,* oöspores (× 600).

spherical bodies about 10 μ in diameter which may germinate a few hours later by one germ tube 2.5 to 3.0 μ in diameter; oögonia subspherical, terminal, produced in great numbers in young cultures and distributed throughout the substratum, 20 to 30 μ (average 25 μ) in diameter; antheridia agchylolaimic, 5 to 7 μ in diameter in the distal expanded portion and 10 to 17 μ in length along curved axis from apex to basal septum, the proximal part more gradually tapering toward delimiting septum to

diameter of supporting filament, 1 to 12 or possibly more often visible in relation to an oögonium, terminal and quite often lateral, on very short branches arising from single hyphae, surrounding the oögonium; oöspores spherical to subspherical, yellowish, mostly plerotic, 25 μ in diameter, produced in young cultures simultaneously with plasmatoögoses and distributed throughout substratum, wall about 1.5 to 2.0 μ in thickness, occurring rarely in the tissues of hosts of very old infections, produced in culture media of Quaker Oats, hempseeds, watermelon seeds, avocado, papaya, etc.

It was obtained from the diseased roots of *Ananas sativus* grown on the island of Molokai of the Hawaiian Archipelago. It is a very aggressive root parasite of *Ananas sativus*, *Saccharum officinarum* var. H 109 and *Lahaina*, *Zea Mays*, *Triticum vulgare*, *Panicum barbinode* and a weak parasite of *Solanum tuberosum* and *Ipomoea Batatas*.

(8) **N. rhizophthoron** sp. nov. (FIG. 7).

Mycelium intra- and extracellular, in culture media exhibiting a moderate aërial development mostly at the margins of the colony; hyphae irregular 3 to 6 μ in diameter (average 4 μ) with laterals terminating in blunt tips or subspherical structures 5 to 10 μ in diameter; plasmatoögoses (on *Carica Papaya* media) not in aggregates, individual units distributed throughout and submerged by substratum, 100 to 400 μ and their hyphae from 10 to 20 μ; occurring in moderate numbers in the tissues of hosts and may or may not fill completely the host cells, produced in 10-day old cultures and in the tissues of hosts in young as well as old infections; zoösporangia developing readily (in 30 minutes) from prosporangia produced on the infected tissues of hosts under proper environmental conditions, 25 to 45 μ in diameter, containing from 4 to 50 biciliate, reniform zoöspores; zoöspores about 10 μ in diameter, at rest, formed in 15 to 20 minutes in the zoösporangium, motile for 10 to 30 minutes or possibly longer, then rounding up as subspherical bodies which may germinate by one, two or three germ tubes 2.5 to 3.0 μ in diameter; oögonia spherical to subspherical, terminal, produced in great numbers in young cultures and distributed throughout substratum, 28 to 40 μ (average 34 μ); antheridia agchylolaimic, 5 to 10 μ in diameter in the distal expanded portion and 12 to 25 μ in length along curved axis from apex to basal septum, the proximal part more gradually tapering toward delimiting septum, to diameter of supporting filament, 1 to 12 or possibly more, often visible in

relation to an oögonium, terminal and quite often lateral; oöspores spherical to subspherical, yellowish, mostly plerotic, 25 to 38 μ (average 33 μ) in diameter and surrounded by a wall about 1.5 to 2.0 μ in thickness, produced in great number in the substratum and tissues of hosts of young and old infections and mostly at the base of root hairs.

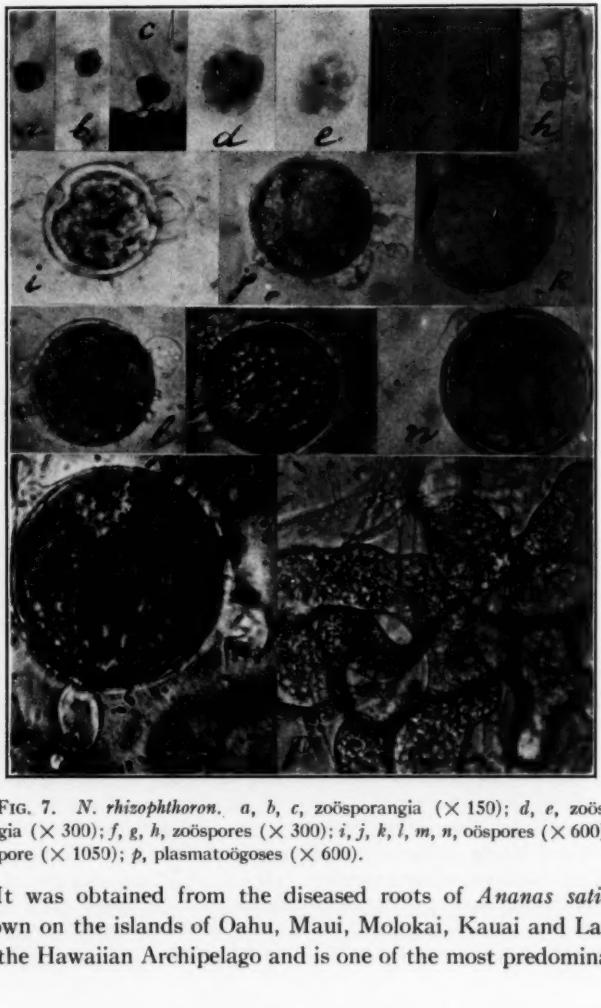


FIG. 7. *N. rhizophthoron*. *a*, *b*, *c*, zoösporangia (× 150); *d*, *e*, zoösporangia (× 300); *f*, *g*, *h*, zoöspores (× 300); *i*, *j*, *k*, *l*, *m*, *n*, oöspores (× 600); *o*, oöspore (× 1050); *p*, plasmatoögoses (× 600).

It was obtained from the diseased roots of *Ananas sativus* grown on the islands of Oahu, Maui, Molokai, Kauai and Lanai of the Hawaiian Archipelago and is one of the most predominant

species in pineapple fields. It is a very aggressive root parasite of *Ananas sativus*, *Saccharum officinarum* var. H 109 and *Lahaina*, *Zea Mays*, *Triticum vulgare*, *Panicum barbinode* and less aggressive on *Solanum tuberosum* and *Ipomoea Batatas*.

(9) **N. leucosticton** sp. nov. (FIG. 8).

Mycelium intra- and extracellular, in culture media exhibiting a moderate aërial development mostly at the margins of the colony; hyphae irregular 3 to 6 μ in diameter (average 4 μ) laterals terminating mostly in subspherical bodies about 20 μ in diameter devoid of protoplasm (these, in the opinion of the writer, are undeveloped oögonia); plasmatoögoses (on *Carica Papaya* media) not in great aggregates, mostly small, 100 to 400 μ, distributed throughout substratum, either submerged or protruding above the surface, in the latter case appearing as small white spots occupying mostly the marginal area of the colony, forming in cultures 2 to 3 weeks old, produced also in moderate quantities in the tissues of hosts; zoösporangia developing readily, from prosporangia produced on the infected tissues of hosts under proper environmental conditions, 25 to 50 μ, containing from 4 to 50 biciliate reniform zoöspores; zoöspores approximately 10 μ in diameter, at rest, formed in 15 to 20 minutes in the zoösporangium, motile for 10 to 30 minutes or possibly longer, then rounding up as subspherical bodies which may germinate by one germ tube 2.5 to 3.0 μ in diameter; oögonia subspherical terminal or lateral, 28 to 40 μ, produced in great numbers, many sterile (failing to produce oöspores even after they become fertilized, remaining as empty spheres and surrounded by 1 to 12 antheridia), produced in one week old cultures and distributed throughout the substratum; antheridia agchylolaimic, 5 to 8 μ in diameter in the distal expanded portion and 15 to 25 μ in length along curved axis from apex to basal septum, the proximal part more gradually tapering toward delimiting septum, to diameter of supporting filament, 1 to 12 or possible more often visible in relation to an oögonium, terminal and quite often lateral; oöspores spherical to subspherical, yellowish, mostly plerotic, 20 to 40 μ in diameter (average 30 μ), surrounded by a wall 1.5 to 2.0 μ in thickness, produced in great numbers in the tissues of hosts in both young and old infections and in the substratum of cultures about one week old.

It was obtained from the diseased roots of *Bilbergia* sp. grown in the greenhouse of the Experiment Station. It is a very aggressive root parasite of *Ananas sativus*, *Saccharum officinarum*

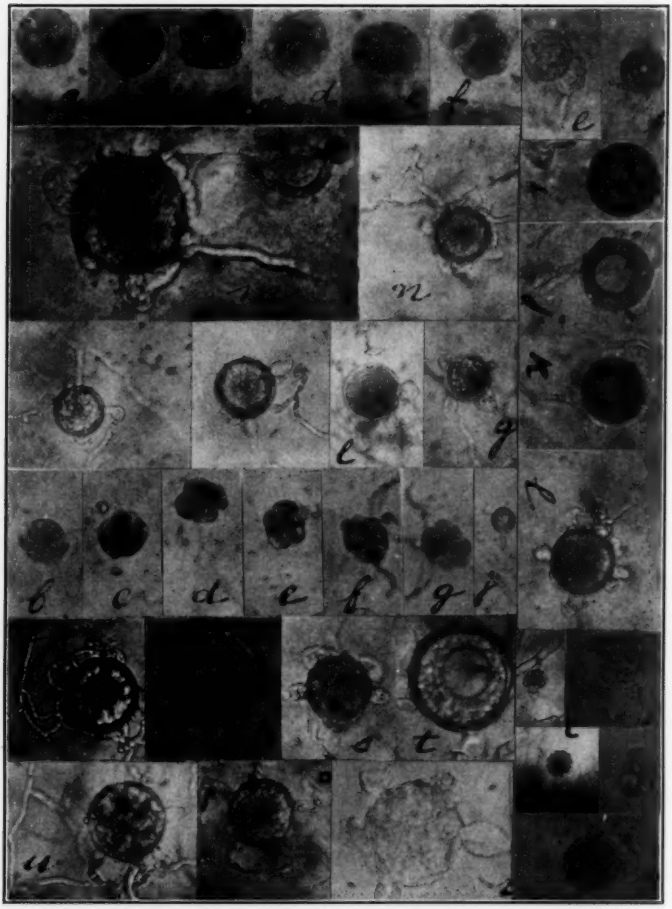


FIG. 8. (right) *N. leucosticton*. *a*, *c*, zoösporangia (× 150); *b*, *d*, zoösporangia (× 300); *e*, *f*, *g*, *h*, *i*, *j*, *k*, *l*, oöspores (× 300); *m*, plasmatoögoses and two undeveloped oögonia; (lower left) *N. leiohyphon*. *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, development of zoösporangium (× 300); *i*, *j*, zoöspores (× 300); *m*, *n*, *p*, *s*, *u*, oöspores (× 300); *r*, *l*, *o*, *t*, oöspores (× 600); *r*, abortive oöspore (× 600); (upper left) *N. epiphanosporon*. *a*, *b*, *c*, *d*, *e*, *f*, development of zoösporangium (× 300); *g*, *l*, *n*, oöspores (× 300); *h*, *i*, *j*, *m*, oöspores (× 600); *k*, oöspore (× 900); *o*, oöspores and antheridia (× 300).

var. H 109 and *Lahaina*, *Zea Mays*, *Triticum vulgare*, *Panicum barbinode* and a less aggressive one on *Ipomoea Batatas*.

(10) **N. leiohyphon** sp. nov. (FIG. 8).

Mycelium intra- and extracellular, in culture media exhibiting either a very faint aërial development or lacking it entirely; hyphae irregular 3 to 6 μ (average 4 μ); plasmatoögoses (on *Carica Papaya* media) not forming large aggregates, 100 to 400 μ, submerged and distributed throughout substratum, produced in 1 to 2 weeks old cultures in moderate quantities and in the tissues of hosts; zoösporangia produced readily, from prosporangia developing on the recently infected tissues of hosts under proper environmental conditions, 25 to 50 μ and containing from 4 to 50 biciliate reniform zoöspores; zoöspores motile for 10 to 30 minutes and then rounding up as subspherical bodies about 12 μ in diameter germinating in a few hours by one or rarely two germ tubes 2.5 to 3.0 μ in diameter; oögonia subspherical, terminal and rarely intercalary, some sterile, 25 to 38 μ (average 32 μ), wall approximately 0.5 μ in thickness; antheridia agchylolaimic, 5 to 8 μ in diameter in the distal expanded portion and 10 to 20 μ in length along curved axis from apex to basal septum, the rounded apical end making narrow contact with oögonium about a short fertilization tube that measures approximately 2.5 μ in diameter, the proximal part more gradually tapering toward delimiting septum, to diameter of supporting filament, 2 to 15 or possibly more often visible in relation to an oögonium; terminal and quite often lateral on branches arising from the same hypha and numbering from 2 to 12; oöspores (on *Carica Papaya* agar or tissues of hosts) subspherical, yellowish, mostly plerotic, 25 to 38 μ (average 32 μ) in diameter, containing a reserve globule often 12 to 19 μ; wall 1.2 to 2.0 μ in thickness; produced in one-week-old cultures and in the tissues of hosts of young as well as old infections.

It was obtained from the diseased roots of *Ananas sativus* grown on Oahu. It is an aggressive root parasite of *Ananas sativus*, *Saccharum officinarum* var. H 109 and *Lahaina*, *Triticum vulgare*, *Zea Mays*, *Panicum barbinode* and a less aggressive one on *Solanum tuberosum*.

(11) **N. epiphanosporon** sp. nov. (FIG. 8).

Mycelium intra- and extracellular, in culture media exhibiting a very profuse aërial development over the entire colony; hyphae irregular about 4 μ and may vary between 3 and 5 μ; plasma-

toögoses (on *Carica Papaya* media) small and few mostly embedded in the substratum and almost indistinguishable by the naked eye, developing in one-week-old cultures, produced either simultaneously with or slightly after the sexual organs, developing into prosporangia or germinating as conidia depending on environmental conditions, occurring in the tissues of hosts in moderate numbers; zoösporangia developing readily in water from prosporangia produced on portions of recently-infected root tissues of hosts, 25 to 60 μ and containing from 4 to 50 and possibly more biciliate reniform zoöspores; zoöspores motile for 10 to 30 minutes and then rounding up as subspherical bodies, about 10 μ in diameter, which may germinate in a few hours by one or rarely two germ tubes 2.5 to 3.0 μ in diameter; oögonia (on *Carica Papaya* agar) subspherical, terminal and rarely intercalary, produced on the aërial mycelium and rarely embedded in the substratum, many sterile, 20 to 40 μ (average 30 μ) with a wall about 0.5 μ in thickness, produced in great numbers in the tissues of hosts; antheridia agchylolaimic, 5 to 8 μ in diameter in the distal expanded portion and 10 to 20 μ in length along curved axis from apex to basal septum, the proximal part more gradually tapering toward delimiting septum to diameter of supporting filament, numerous from 2 to 8 or possibly more often visible in relation to an oögonium, terminal and sometimes lateral; oöspores subspherical, yellowish mostly plerotic, 20 to 40 μ (average 30 μ), containing a reserve globule and surrounded by a wall 1.2 to 2.2 μ in thickness, produced in relatively great numbers in the tissues of hosts.

It was obtained from the diseased roots of *Ananas sativus* grown on the island of Oahu of the Hawaiian Archipelago. It is an aggressive root parasite of *Ananas sativus*, *Saccharum officinarum* var. H 109 and *Lahaina*, *Zea Mays*, *Triticum vulgare*, *Panicum barbinode* and a less aggressive one on *Solanum tuberosum*.

(12) *N. aphanidermatum* (Edson) Fitzpatrick (FIG. 9).

(*Rheosporangium aphanidermatum* Edson, Jour. Agr. Res. **4**: 279–291. 1915.)

Pythium aphanidermatum Fitzpatrick; (*Nematosporangium aphanidermatum* Fitzpatrick, Mycologia **15**: 166–173. 1923.)

Mycelium intra- and extracellular, in culture media exhibiting a very profuse aërial development and extremely rapid growth (the colony being able to make a growth 100 mm. in diameter in

48 hours); hyphae irregular, those of the aërial mycelium producing many branches at the tips, showing false dichotomy measuring from 3 to 8 μ in diameter and occasionally septate

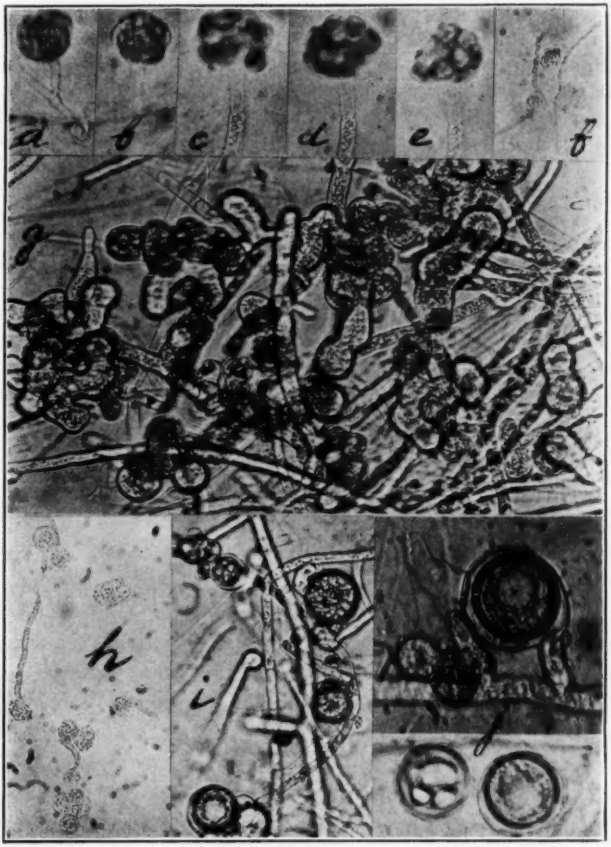


FIG. 9. *N. aphanidermatum* (Edson) Fitzpatrick. *a*, *b*, *c*, *d*, *e*, development of zoösporangium (× 300); *f*, *h*, zoöspores germinating (× 300); *g*, plasmatoögoses on aerial mycelium; *i*, oöspores (× 300); *j*, oöspores (× 600).

in old cultures; plasmatoögoses in great number on the aërial mycelium, not forming aggregates and occasionally embedded in the substratum, in the tissues of hosts forming in moderate

quantities; zoösporangia forming readily from prosporangia in hanging-drop cultures, at temperatures between 25° and 30° C, measuring on an average 45 μ and containing 4 to 60 biciliate reniform zoöspores; zoöspores produced in the zoösporangium in 15 to 20 minutes, motile for 10 to 30 minutes then rounding up as subspherical bodies 8 to 12 μ in diameter which may germinate in a few hours by a single germ tube 2.5 to 3.0 μ in diameter; oögonia very numerous, on most substrata borne laterally on very short budlike branches but may be intercalary on the aërial mycelium (seldom on the submerged mycelium), subspherical, thin-walled, 20 to 30 μ (average 25 μ) in diameter; antheridia terminal or intercalary doliform or broadly clavate, 9 to 11 μ in diameter in the distal expanded portion and 10 to 14 μ in length along axis from apex to basal septum, supporting filament very short 3 to 6 μ in length and occasionally slightly longer, 1 to 2 and rarely 3 to 4 visible in relation to an oögonium; oöspores spherical to subspherical, single, aplerotic with a reserve globule, wall 1.0 to 2.0 μ in thickness, produced in greater numbers on the aërial than submerged mycelium, and in moderate numbers in the tissues of hosts.

It was first obtained from seedlings of *Beta vulgaris* by Edson and since isolated from many other plants. It is a root parasite of many plants including *Ananas sativus*.

(13) *N. aphanidermatum* var. **hawaiiensis** var. nov. (FIG. 10).

This organism differs from *N. aphanidermatum* (Edson) Fitzpatrick in the less vigorous production of aërial mycelium, the slightly branched tips of the aërial hyphae, the slower and rarer production of oöspores and of zoösporangia from plasmatoögoses. It was found on the diseased roots of *Carica Papaya* grown in the writer's garden in Manoa Valley, in the City of Honolulu.

(14) **N. Butleri** (Subram.) comb. nov. (FIG. 11).

(*Pythium Butleri* Subram. Mem. Dept. Agr. India, Bot. Ser. **10**: No. 4. 1919.)

Mycelium intra- and extracellular, in most culture media exhibiting a profuse aërial development and a relatively rapid growth; hyphae irregular, those of the aërial mycelium often producing thysanoid growth at their tips, with false dichotomy, 3 to 8 μ in diameter and frequently septate in old cultures; plasmatoögoses in great number on the aërial mycelium, never

uniting to form aggregates, and occasionally embedded in the substratum and tissues of hosts, developing often into prosporangia; zoösporangia forming in 2 hours from prosporangia in hanging drop cultures, at temperatures between 25° and 30° C, measuring on an average 45 μ (ranging between 20 and 120 μ)

FIG. 10. *N. aphanidermatum* var. *hawaiiensis*. Sexual organs (× 600).

and containing 4 to 60 biciliate reniform zoöspores; zoöspores produced in the zoösporangium in 15 to 20 minutes, motile for 30 minutes then rounding up as subspherical bodies 8 to 12 μ in diameter which may germinate in a few hours by a single germ tube; oögonia not very numerous, produced in 3 to 7 days on most substrata, lateral and intercalary on very short budlike branches or longer branches of the aërial mycelium and occasionally on the embedded mycelium, subspherical and thin-walled, 20 to 30 μ in diameter; antheridia terminal or on very short laterals broadly clavate, 9 to 11 μ in diameter in the distal expanded portion and 10 to 14 μ in length along axis from apex

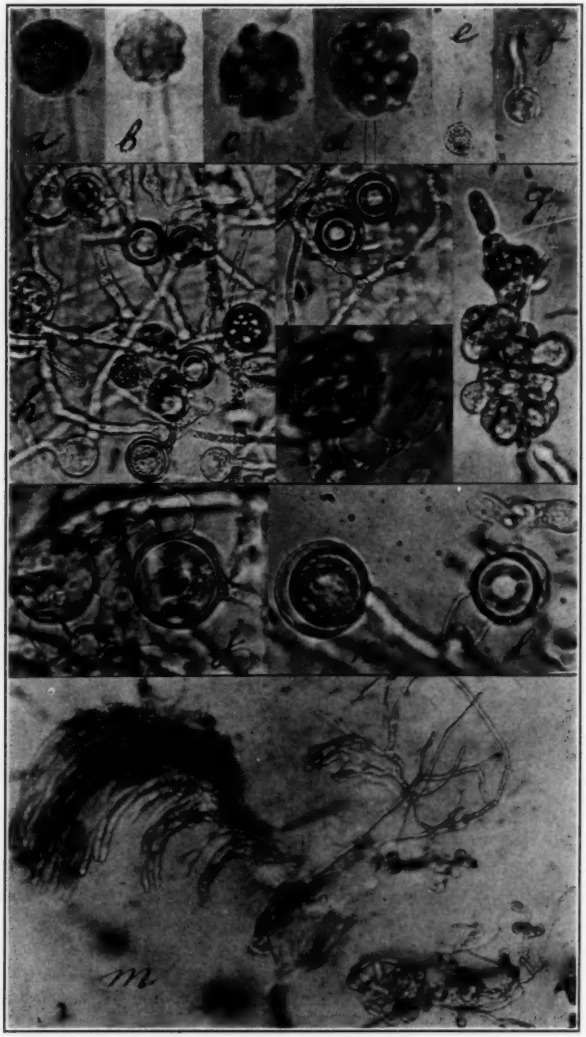


FIG. 11. *N. Butleri* (Subramanian). *a, b, c, d,* development of zöosporangium (× 300); *e, f,* zoöspores germinating (× 300); *g,* plasmatoögoses on aerial mycelium; *h,* oöspores (× 300); *i, j, k, l,* oöspores (× 600); *m,* tip of aerial hypha-thsanoid structure.

to basal septum; supporting filament mostly short 3 to 6 μ in length and occasionally slightly longer, 1 to 2 and seldom 3 visible in relation to an oögonium; oöspores spherical to subspherical, single, not numerous, aplerotic, wall 1.0 to 2.0 μ in thickness; not very numerous in the tissues of hosts or various culture media.

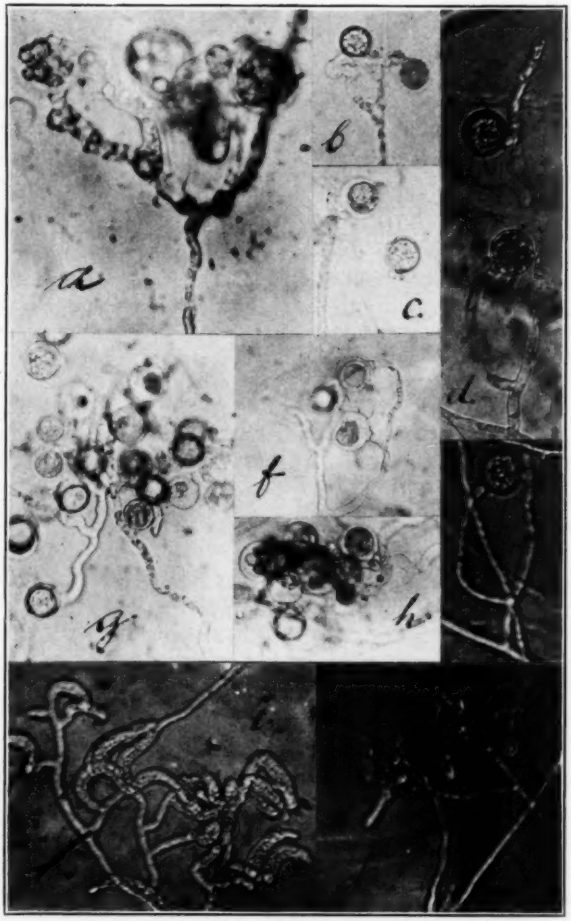


FIG. 12. *N. Indigoferae* (Butler). *a*, oöspores (× 600); *b*, *c*, *d*, *e*, *f*, *g*, *h*, oöspores (× 300); *i*, *j*, plasmatoögoses on aerial mycelium.

It was obtained by Subramanian from the diseased roots of *Carica Papaya, Zingiber officinalis* and *Nicotiana Tabacum* grown in India. It is a root parasite of many plants including *Ananas sativus*.

(15) **N. indigoferae** (Butler) comb. nov. (FIG. 12).

(*Pythium Indigoferae* Butler, Mem. Dep. Agr. India **1**: No. 5. 1907.)

Mycelium intra- and extracellular, in culture media exhibiting a moderate to faint aërial development; hyphae irregular in size 3 to 5 μ in diameter; plasmatoögoses in moderate numbers on the aërial mycelium, not forming aggregates and rarely, if ever, developing into prosporangia, but instead into sexual organs; zoösporangia, developing very seldom, and according to Butler (2) very small, opening laterally by short straight branches, producing from 4 to 20 zoöspores; zoöspores about 10 μ in diameter, at rest, reniform and biciliate; oögonia terminal mostly on rather short lateral branches or in the lateral outgrowths of plasmatoögoses, very constant in size, 18 to 20 μ in diameter, oögonial stalk or supporting filament strongly curved towards the antheridium producing a characteristic appearance; antheridia cylindrical or doliform, straight, 4 to 7 μ in diameter and 8 to 12 μ in length along axis from apex to basal septum, terminal or on very short laterals supporting filament in the latter either lacking entirely or extremely short; oöspores spherical to subspherical, aplerotic smooth 10 to 16 μ in diameter, germinating rapidly by a hypha, not by zoöspores.

It was obtained from the leaves of *Indigofera arrecta* Hochst., by Butler and by McRae [11] from the roots of *Cucumis sativus* in India. It is a saprophyte but may under certain conditions enter the tip of the roots of *Ananas sativus*.

DISCUSSION

Schröter doubtless raised *Nematosporangium* to generic rank because of the morphological differences between the prosporangia of the two genera *Pythium* and *Nematosporangium*, which differences are of fundamental importance. If we were dealing with only one or two species of *Nematosporangium* then we might have been justified in permitting these few distantly-related

[11] This organism was sent to the writer by Dr. W. McRae of the Agricultural Research Institute, Pusa, India.

organisms to remain in the genus *Pythium*. But, as long as we have more than a dozen and as long as these organisms fall into a number of subgroups and require further subdivision for their identification, our non-recognition of the generic rank of *Nematosporangium*, besides being unscientific, tends to cause confusion and stop our further progress.

The morphological features of the genus *Nematosporangium* have been discussed quite extensively in the preceding paragraphs. As morphological differences in the shape and size of oögonia, oöspores, antheridia, prosporangia or zoöspores between species of the same section are almost insignificant, rarely exceeding those of normal variation, the adoption of such characters for differentiation would have been misleading. Physiological and certain morphological differences, however, have been found to be fairly constant as well as stable in certain culture media and for this reason they have been adopted for the differentiation and taxonomic classification of the various species. It is rather difficult, if not impossible, to explain satisfactorily the behavior of the different species of *Nematosporangium* on the various culture media, and especially *Carica Papaya* used in these studies. As other organisms such as various species of *Pythium*, *Phytophthora*, and members of Fungi Imperfecti, such as *Fusarium*, *Verticillium*, etc., have been found to make an excellent and normal growth on *Carica Papaya*, the explanation is that, in respect to *Carica Papaya*, it incorporates all the essential food substances for the normal growth of these organisms. It has been found that very dilute concentrations of *Carica Papaya* juice will not produce normal growth in the different fungi. Temperature differences between 22° and 32° C. influence but slightly the physiological behavior of species of *Nematosporangium*. Low temperature may retard and high temperature may accelerate the rate of growth but the differentiating features of the various organisms are always produced.

The various sections have been created to facilitate the grouping of organisms according to certain differences existing in their sexual reproduction. The section *Polyandra* differs from *Oligandra* in the great number of antheridia that are found in relation to a single oögonium. As many as twenty-five antheridia

have been observed by Drechsler on *N. arrhenomanes*. Moreover, the antheridia of the section *Polyandra*, borne either terminally or laterally, are supported on a fairly long stalk, ranging from one to many times the length of the antheridium proper. The section *Oligandra* is characterized by the small number of antheridia, one or sometimes two, in relation to a single oögonium. The antheridia of the section *Oligandra* differ in shape considerably from those of the section *Polyandra*. They are bud-like or barrel-shaped with very slight tapering or none, and the supporting hypha is either very short or almost obsolete. The diameter of the antheridium in its relation to the length is rather great. Other morphological differences between the two sections may be found in the oöspores. The oöspores of all the members of the section *Polyandra* are considerably larger in diameter and mostly fill the oögonium, whereas, those of the section *Oligandra* are about 8 to 10 μ smaller in diameter and never or very rarely fill the oögonium. Besides, the organisms of the section *Oligandra* produce oöspores and prosporangia mostly on the aërial mycelium or surface of the substratum, whereas, those of the section *Polyandra* produce them mostly in the substratum, except in *N. epiphanosporon*, which produces them in and on the substratum.

The section *Polyandra* is divided into three subsections, namely, *Bradyspora*, *Hemibradyspora* and *Tachyspora*. The members of the first and second subsections require special culture media, such as juice of the ripe fruit of *Carica Papaya* or a decoction of the seeds of various plants and these in sufficient concentration for their sexual reproduction. Those of the third, however, reproduce sexually in a greater variety of culture media than the former. The organisms of the subsections *Bradyspora* and *Hemibradyspora* reproduce sexually very rarely or never or only in old infections in the tissues of hosts, the probable explanation thereof being that such tissues do not contain food substances in sufficient concentration to enable the rather wasteful process of sexual reproduction of these organisms. Or, it may be that they have to build up sufficient protoplasmic matter for their sexual reproduction and such a process requires very long time, this explaining the production of sexual organs only in old infec-

tions and cultures. The members of the subsection *Tachyspora* reproduce sexually very readily in the tissues of hosts, their oöspores being embedded usually in the exodermal layer of cells of roots. Members of the two subsections may be easily differentiated in the tissues of hosts merely by the presence or absence of oöspores. Between members of the subsection *Tachyspora*, their identification may be made on the relative number of oöspores in the tissues of hosts. *N. rhizophthoron* produces many well-developed and fertile oöspores and likewise many plasmatoögoses. *N. leucosticton* produces fewer oöspores, some of them abortive, and fewer plasmatoögoses. *N. leiohyphon* produces very few oöspores, mostly abortive, and extremely few plasmatoögoses. *N. epiphanosporon* may produce many oöspores but all of them are abortive, there may be an exception occasionally and very few plasmatoögoses. *N. rhizophthoron* is the most predominant root parasite in pineapple fields, followed by *N. polyandron* and *N. hyphalosticton*. The writer is of the opinion that the wide distribution of *N. rhizophthoron* is due to its ability to produce many fertile oöspores.

The section *Oligandra* is divided into the subsections *Plethorocomba* and *Oligocomba*, the former including those members with many plasmatoögoses and the latter those with very few. The members of *Plethorocomba* produce zoösporangia from their plasmatoögoses quite readily in water, indicating that they are hydrobiotic organisms, whereas those of *Oligocomba* produce them very rarely indicating their aërial or terrestrial habitat. The production of oöspores by members of *Oligocomba* is considerably more abundant than by those of *Plethorocomba*, this being an additional evidence of the influence of habitat on the reproduction of the two different groups.

The morphological characteristics of the colonies of different species in the same subsection cannot be attributed to anything else than the inherent physiological behavior of each organism. These differences, constituting a fairly reliable criterion of differentiation between closely related species, are only produced in *Carica Papaya* agar media. The differentiation of species on the basis of a summation of all characters can be easily made out, however, by growing the organisms in the various culture media above-mentioned.

A brief analysis of the ontogenetic and phylogenetic development of the different species of *Nematosporangium* indicates that the members of the section *Oligandra* are more primitive and therefore more elementary in behavior than those of the section *Polyandra*. The evidence for such a characterization of the members of the section *Oligandra* is based on morphological characters such as (1) the great abundance of plasmatoögoses developing mostly into prosporangia on the aërial mycelium, (2) the aplerotic type of oöspores and (3) the rudimentary or primitive type of antheridium. The plasmatoögoses of members of the *Oligandra* except those of *N. Indigoferae* may all develop into prosporangia under favorable conditions and their protoplasm be converted entirely into zoöspores, whereas those of section *Polyandra* do not develop into prosporangia as readily, but conserve their protoplasm for vegetative propagation, a safer method under slightly adverse conditions. Such differences reveal that the members of the section *Oligandra* except *N. Indigoferae* are aquatic forms, whereas those of the section *Polyandra* are terrestrial forms.

The writer wishes to acknowledge his indebtedness to Dr. A. L. Dean and Dr. G. H. Godfrey for reading the manuscript and to express his thanks to Dr. J. T. Barrett of the University of California for the use of his laboratory for part of this work and to Mr. G. E. Paxton and Mrs. M. W. Lorimer for technical assistance.

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NOTES ON NEW SPECIES OF USTILAGINALES [1]

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The descriptions of the following ten new species and one new combination are based on specimens sent to the author by members of the Union Department of Agriculture, Pretoria, Union of South Africa, and by Ross W. Davidson of the office of Mycology and Disease Survey, United States Department of Agriculture. The specimens from the United States Department of Agriculture are from collections made by Mrs. Agnes Chase in Brazil and she has determined all hosts originating from Brazil.

Ustilago braziliensis sp. nov.

Sori spherical, covered with a dark membrane, entirely destroying the ovaries, having the general appearance of a panicle of ripe seeds; about 1 mm. in diam.; spore-mass olive green; spores regular, globose, usually 8 μ diam., sometimes up to 10 μ, reddish brown, under oil immersion abundantly papillate.

On *Panicum rivulare* Trin.: Viçosa, Minas Geraes, Brazil; coll. Agnes Chase, April 11, 1925 (U. S. Dept. Agr. Myc. Coll. No. *60382*).

Ustilago gregaria sp. nov.

Sori in groups along the side branches of the panicle, completely destroying the ovaries which are swollen, globose, about 2 mm. diam., covered with a dark membrane which upon rupturing reveals a dark olive brown spore-mass; spores regular, globose, deep olive brown, usually 6–8 μ diam., occasionally 10 μ; under oil immersion abundantly echinulate, sometimes guttulate.

On *Panicum rivulare* Trin.: Juiz de Fora, Minas Geraes, Brazil; coll. Agnes Chase. February 1925. (U. S. Dept. Agr. Myc. Coll. No. *60384*.)

[1] Contribution from The Department of Botany, The Pennsylvania State College No. 75.

Farysia Pseudocyperi (Sacc.) comb. nov.

Ustilago olivacea forma *Pseudocyperi* Sacc., Syll. 7: 463. 1888.

Sori entirely destroying the ovary, converting it into an olive brown dusty mass of shreds and spores; spores borne between sterile elators or shreds, globose-subglobose, occasionally oblong, olive brown with a distinct thick outer dark olive brown exospore, under oil immersion minutely verruculose, 6–10 μ diam.

On Cyperaceae (undet. genus); Sin Koong, North Kwangtung, China; coll. F. A. McClure, January 10, 1926. (Unnumbered specimen from U. S. Dept. Agr. Myc. Coll.)

This species differs from *Farysia* (*Ustilago*) *olivacea* in having larger spores. It has been previously reported from Argentina on *Carex Pseudo-cyperus* L.

Sphacelotheca Chaseae sp. nov.

Sori destroying the individual florets along the rachis of the spike, 4–5 mm. long, covered with a delicate hyaline membrane which dehisces exposing an agglutinated mass of dark brown spores surrounding a columella; cells of the sterile tissue not easily separated; spores 4–6 μ diam., globose-subglobose, gullulate; light reddish brown; under oil immersion smooth.

On *Mesosetum ferrugineum* (Trin.) Chase; Serra do Cipo, Minas Geraes, Brazil; Coll. Agnes Chase, March 28 and April 1, 1925. (U. S. Dept. Agr. Myc. Coll. No. *60374* and No. *60377*.)

Sphacelotheca braziliensis sp. nov.

Sori in the ovaries not concealed by the glumes, 2 mm. long, covered with a delicate yellowish membrane; sterile cells singly, in chains or in groups; globose or irregular due to compression; spores globose-subglobose, light reddish brown, 8–12 μ diam., under oil immersion minutely but abundantly echinulate.

On *Andropogon leucostachyus* H.B.K.: Serra do Cipo, Minas Geraes, Brazil; Coll. Agnes Chase, March 28 and April 1, 1925. (U. S. Dept. Agr. Myc. Coll. No. *60376*.)

Of the other species described as occurring on this host, *viz.* *Sphacelotheca leucostachys* (P. Henn.) Zundel; *Sphacelotheca Kellermanii* Clinton & Zundel; and *Sphacelotheca Holwayi* Clinton & Zundel, this species differs in the small sorus, lighter colored and smaller spores.

Sphacelotheca echinata sp. nov.

Sori destroying the inflorescence, about 1 cm. long, globose, covered with a dark olive, thick, false membrane which upon maturity ruptures disclosing a brown spore-mass surrounding a columella, false membrane more or less persistent, not easily separated into sterile cells; large sterile cells, about the size of the spores, scattered throughout the sorus; spores globose-subglobose, guttulate, 10–14 μ diam.; under oil immersion abundantly echinulate.

On *Panicum demissum* Trin.: Serra do Caparaó, Brazil; Coll. Agnes Chase, April 20–May 4, 1925. (U. S. Dept. Agr. Myc. Coll. No. *60371*.)

On *Panicum missionum* Mez.: Campos do Jordão, Serra Mantiqueira, Brazil; Coll. Agnes Chase, May 20–22, 1925. (U. S. Dept. Agr. Myc. Coll. No. *60358*.)

Sphacelotheca Mesoseti sp. nov.

Sori in the inflorescence, destroying the ovary about 3 mm. long, usually all ovaries on an infected spike destroyed, covered with a delicate membrane which breaks up into single or chains of sterile cells, sterile cells globose-subglobose or linear, globose cells 10–14 μ diam.; spores reddish brown, globose-subglobose, 10–14 μ diam.; under oil immersion smooth with a delicate epispore that is easily ruptured.

On *Mesosetum loliiforme* (Hochst.) Chase: Parafuso, Bahia, Brazil; Coll. Agnes Chase, Dec. 22, 1924. (U. S. Dept. Agr. Myc. Coll. No. *60389*.)

Sphacelotheca Vryburgii sp. nov.

Sori in the inflorescence, at first hidden by the glumes but later exposed, long linear 5–10 mm. long, covered by a reddish brown, delicate false membrane which flakes away revealing an agglutinated mass of black spores surrounding a well developed, much branched columella; sterile cells hyaline globose, usually in groups, variable in size, 9–15 μ diam.; spores globose-subglobose occasionally angled, very light reddish brown, 4–8 μ diam.; under oil immersion smooth, contents finely granular with a hyaline-like light colored wall.

On *Themeda Forskallii* Kunth.: Vryburg, British Bechuanaland, Union of South Africa; Coll. I. B. Pole Evans, May 5, 1916. (Union Dept. Agr. South Africa, Myc. Herb. No. *9733*.)

Cintractia dubiosa sp. nov.

Sori in the ovary at first completely hidden by the glumes but later the tip partly protruding, spherical, very firmly agglutinated, hard; spores reddish-brown, with a thick dark reddish epispore but lighter in the center, globose-subglobose, often angular, apparently smooth but under oil immersion minutely papillate, 12–14 μ diam.

On *Pennisetum* sp.: From Nairobi, British East Africa; Coll. H. L. Shantz, September 9, 1920. (Unnumbered specimen U. S. Dept. Agr. Myc. Coll.)

It is usually considered that the hosts of *Cintractia* are confined to the Cyperaceae. The author is very dubious about placing the above-named species in *Cintractia*. Every character, however, seems to indicate that this species is a *Cintractia* and until more detailed studies are possible this species will be provisionally placed in the genus *Cintractia*.

Tilletia Paspali sp. nov.

Sori destroying the ovaries, about 1 mm. long, covered by a delicate membrane which ruptures transforming the entire inflorescence into a black "smutty" mass; spores reddish brown, regular, globose-subglobose, often guttulate, 18–22 μ diam.; under oil immersion abundantly echinulate.

On *Paspalum millegrana* Schrad.: Matta de São João, Bahia, Brazil; Coll. Agnes Chase, January 3, 1925. (U. S. Dept. Agr. Myc. Coll. No. *60385*.)

Tilletia transvaalensis sp. nov.

Sori in the ovaries, about 1 mm. long, at first concealed by the glumes but later the tip protrudes slightly, infected spikelets scattered throughout the panicle. Spores regular, globose-subglobose, ranging from a yellowish to a reddish-brown color, 20–26 μ diam., under oil immersion very prominent, large, echinulate. Sterile cells hyaline, usually smaller than the spores.

On *Eragrostis aspera:* Mucklenburg, Zebediela district, Transvaal, Union of South Africa, Coll. G. W. Wearing, June 6, 1913. (Union Dept. Agr. Myc. Herb. No. *25463*.)

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A LIST OF DISEASES OF ECONOMIC PLANTS IN ALABAMA

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Almost three decades have elapsed since anything has been written concerning the fungi of Alabama. Because of the very large number of fungi that have been reported since that time and the increasing interest of the people in this group of plants it has seemed most desirable to present this information in permanent form so as to be available to the people of Alabama, as well as to other workers in the same field outside the state.

The early knowledge of the extent and distribution of fungi in the state is due to the efforts of T. M. Peters and John T. Beaumont. Their collections were identified and described by M. J. Berkeley and M. A. Curtis in the first to third volumes of Grevillea (1872 to 1876) under the title of "Notice of North American Fungi." Some of Peters' earlier collections were sent to H. W. Ravenel and were distributed in Ravenel's Fungi Caroliniana Exsiccati (1852 to 1860).

Nothing more was done toward making known the mycological flora of the state until G. F. Atkinson came to the state in 1889. Atkinson added considerably to the list of parasitic forms, publishing several papers on fungi during his stay in the state and after going to Cornell University. His field work was confined chiefly to the immediate territory of the college and the results of this study were published in Cornell University Bulletin, volume 3, number 1, 1897.

Atkinson was succeeded by L. M. Underwood and F. S. Earle. They devoted considerable time to collecting fungi and covered a rather extensive portion of the state. The result of their work, "A Preliminary List of Alabama Fungi," was published as Bulletin 80 of the Alabama Experiment Station in 1897.

All of the fungi collected in the state up to and including those mentioned in the publications of Underwood and Earle are included in "Plant Life of Alabama," by Dr. Charles T.

Mohr, published in 1901 as a contribution from the United States National Herbarium.

In all of the reports on Alabama fungi mentioned before both parasitic and saprophytic forms on all hosts, regardless of their economic importance, have been included. In the present list only the fungi which occur on economic hosts have been considered. This list has been compiled from specimens and records of the various workers in Plant Pathology in the state since the publication of the paper by Underwood and Earle. In the main the record of fungi in this paper dates from October, 1920, for at that time the building housing all the records and specimens of fungi was destroyed by fire. This list is by no means complete but it is hoped that it may stimulate more interest in the subject so that all who can will add to our information.

Because there is no general agreement with regard to the names of fungus parasites those which are in most general use at present have been employed.

All economically important parasitic and non-parasitic diseases known to occur in the state have been listed. The parasitic diseases are given in alphabetical order according to their common name with the scientific name in parenthesis following. These are followed by the non-parasitic diseases and those for which no pathogen is known. These are indicated respectively by "Non-par" and "Undet."

The scientific and common names of the host included in this paper are those used in "Standardized Plant Names," as adopted by the American Joint Committee on Horticultural Nomenclature, 1923.

LIST OF ECONOMIC HOSTS WITH SOME OF THEIR DISEASES

Alfalfa (*Medicago sativa*): Crown Wart (*Urophlyctis Alfalfae*); Wilt (*Aplanobacter insidiosum*).

Alnus (*Alnus incana*): Catkin deformation (*Taphrina Robinsoniana*).

Apple (*Malus sylvestris*): Bitter rot (*Glomerella cingulata*); Blight (*Bacillus amylovorus*); Black rot (*Physalospora Cydoniae*); Black root-rot (*Xylaria* sp.); Blotch (*Phyllosticta solitaria*); Hypochnose (*Corticium Stevensii*); Rust (*Gymnosporangium globosum*); Rust (*Gymnosporangium Juniperi-virginianae*); Scab (*Venturia inaequalis*); *Septobasidium* canker (*Septobasidium pedicillatum*); Sooty blotch (*Gloeodes pomigena*).

Aster (*Callistephus chinensis*): Wilt (*Fusarium conglutinans Callistephi*).

Avocado (*Persea americana*): Leaf spot (*Phyllosticta micropunctata*).

Azalea (*Rhododendron* sp.): Gall (*Exobasidium Vaccinii*).

Bean (*Phaseolus vulgaris*): Anthracnose (*Colletotrichum Lindemuthianum*); Bacterial blight (*Bacterium Phaseoli*); Dry root-rot (*Fusarium Marti Phaseoli*); Leaf spot (*Cercospora cruenta*); Rust (*Uromyces appendiculatus*); Southern blight (*Sclerotium Rolfsii*); Stem rot (*Corticium vagum*); Mosaic (Undet.).

Bean, Scarlet Runner (*Phaseolus coccineus*): Leaf spot (*Cercospora cruenta*); Rust (*Uromyces appendiculatus*).

Beech, Blue (*Carpinus caroliniana*): Powdery mildew (*Phyllactinia corylea*).

Bignonia (*Bignonia capreolata*): Leaf spot (*Cercospora capreolata*).

Blackberry (*Rubus* sp.): Rust (*Gymnoconia interstitialis*).

Cabbage (*Brassica oleracea*): Black leg (*Phoma lingam*); Black mold (*Alternaria Brassicae*); Black rot (*Pseudomonas campestris*); Downy mildew (*Peronospora parasitica*); Southern blight (*Sclerotium Rolfsii*); Yellows (*Fusarium conglutinans*).

Camphor (*Cinnamomum Camphora*): Anthracnose (*Gloeosporium Camphorae*).

Cantaloupe (*Cucumis Melo*): Downy mildew (*Peronoplasmopara cubensis*); Leaf blight (*Macrosporium cucumerinum*).

Cedar, Red (*Juniper virginiana*): Cedar blight (*Phomopsis juniperovora*); Rust (*Gymnosporangium bermudianum*).

Chrysanthemum (*Chrysanthemum* sp.): Leaf spot (*Cylindrosporium Chrysanthemi*); Wilt (*Fusarium* sp.).

Citrus (*Citrus* sp.): Anthracnose stain (*Colletotrichum gloeosporioides*); Canker (*Bacterium Citri*); Melanose (*Phomopsis Citri*); Scab (*Cladosporium Citri*); *Septobasidium* canker (*Septobasidium pedicillatum*).

Clematis (*Clematis* sp.): Leaf spot (*Cylindrosporium Clematidis*).

Clover, Bur (*Medicago Medicaginis*): Leaf spot (*Cercospora Medicaginis*).

Clover, Red (*Trifolium pratense*): Anthracnose (*Colletotrichum Trifolii*); Powdery mildew (*Erysiphe Polygoni*).

Collard (*Brassica oleracea acephela*): Stem rot (*Sclerotium Rolfsii*); Wilt (*Fusarium conglutinans*).

Corn (*Zea Mays*): Brown spot (*Physoderma Zeae-maydis*); Root-rot (*Fusarium* sp.); Smut (*Ustilago Zeae*).

Cotton (*Gossypium hirsutum*): Angular leaf-spot (*Pseudomonas malvacearum*); Anthracnose (*Glomerella Gossypii*); *Ascochyta* blight (*Ascochyta Gossypii*); Wilt (*Fusarium vasinfectum*).

Cowpea (*Vigna sinensis*): Anthracnose (*Colletotrichum Lindemuthianum*); Mildew (*Erysiphe Polygoni*); Rust (*Uromyces Vignae*); Scab (*Cladosporium Vignae*); Stem rot (*Corticium vagum*); Mosaic (Undet.).

Crape myrtle (*Lagerstroemia australiana*): Powdery mildew (*Uncinula australiana*).

Cucumber (*Cucumis sativus*): Anthracnose (*Colletotrichum lagenarium*); Downy mildew (*Peronoplasmopara cubensis*); Wilt (*Bacillus tracheiphilus*).

Dewberry (*Rubus* sp.): Anthracnose (*Plectodiscella veneta*); Double blossom (*Fusisporium Rubi*); Cane blight (*Leptosphaeria Coniothyrium*).

Dogwood (*Cornus* sp.): Leaf spot (*Cercospora cornicola*).

Eggplant (*Solanum Melongena*): Blight (*Phomopsis vexans*).

Elm (*Ulmus* sp.): Leaf spot (*Gnomonia ulmea*); Mildew (*Uncinula* sp.).

Euonymus (*Euonymus* sp.): Anthracnose (*Colletotrichum griseum*); Leaf spot (*Exosporium concentricum*).
Fig (*Ficus Carica*): Anthracnose (*Colletotrichum Carica*); Leaf spot (*Cercospora bolleana*); Rust (*Physopella Fici*).
Geranium (*Pelargonium* sp.): Bacterial leaf-spot (*Bacterium Erodii*).
Grape (*Vitis* sp.): Black rot (*Guignardia Bidwellii*).
Hibiscus (*Hibiscus syriacus*): Rust (*Kuehneola malvicola*).
Hickory (*Hicoria* spp.): Anthracnose (*Gnomonia Caryae*).
Holly (*Ilex* spp.): Tar spot (*Rhytisma ilicincola*).
Iris (*Iris* spp.): Leaf spot (*Heterosporium gracile*).
Japonica (*Camellia japonica*): Leaf spot (*Phyllosticta camelliacola*).
Larkspur (*Delphinium* spp.): Stem rot (*Sclerotium Rolfsii*).
Laurel, Mountain (*Kalmia latifolia*); Leaf spot (*Phyllosticta kalmicola*).
Lettuce (*Lactuca sativa*): Drop (*Sclerotinia sclerotiorum*).
Lilac (*Syringa vulgaris*): Leaf spot (*Cercospora Lilacis*).
Magnolia (*Magnolia* spp.): Leaf spot (*Phyllosticta Cookei*).
Maple (*Acer* sp.): Leaf spot (*Phyllosticta acericola*); Wilt (*Verticillium* sp.).
Mulberry (*Morus* sp.): Popcorn disease (*Sclerotinia carunculoides*).
Oak (*Quercus nigra*): Leaf blister (*Taphrina coerulescens*); Leaf spot (*Marssonia Martini*).
Oats (*Avena sativa*): Crown rust (*Puccinia coronata*); Loose smut (*Ustilago Avenae*).
Okra (*Hibiscus esculentus*): Wilt (*Fusarium vasinfectum*).
Oleander (*Nerium Oleander*): Leaf spot (*Macrosporium Nerii*).
Onion (*Allium cepa*): Neck rot (*Botrytis Allii*); Soft rot (*Bacillus carotovorus*).
Palm (*Phoenix* spp.): False smut (*Graphiola Phoenicis*).
Peach (*Amygdalus persica*): Brown rot (*Sclerotinia fructicola*); Crown gall (*Bacterium tumefaciens*); Curl (*Taphrina deformans*); Scab (*Cladosporium carpophilum*); Shot hole (*Bacterium Pruni*); Rosette (Undet.).
Peanut (*Arachis hypogaea*): Leaf spot (*Cercospora personata*).
Pear (*Pyrus communis*): Bitter rot (*Glomerella cingulata*); Blight (*Bacillus amylovorus*); Brown rot (*Sclerotinia fructicola*); Flyspeck (*Leptothyrium carpophilum*); Fruit rot (*Phytophthora cactorum*); Leaf spot (*Phyllosticta pyrina*); Leaf spot (*Pestalozzia Guepini*); Scab (*Venturia pyrina*); *Septobasidium* canker (*Septobasidium retiforme*).
Pecan (*Hicoria pecan*): Anthracnose (*Glomerella cingulata*); Brown leaf spot (*Cercospora fusca*); Crown gall (*Bacterium tumefaciens*); *Myriangium* disease (*Myriangium tuberculans*); Nursery blight (*Phyllosticta Caryae*); Powdery mildew (*Microsphaera Alni*); Scab (*Cladosporium effusum*); Septobasidium canker (*Septobasidium retiforme*); Rosette (Undet.).
Peony (*Paeonia* sp.): Blight (*Botrytis Paeoniae*); Leaf mold (*Cladosporium Paeoniae*).
Pepper, Bell (*Capsicum annum*): Bacterial wilt (*Bacterium solanacearum*); Rot (*Phoma destructiva*); Southern blight (*Sclerotium Rolfsii*); Blossom end-rot (Non-par.).
Persimmon, Japanese (*Diospyros kaki*): Leaf spot (*Cercospora fuliginosa*).
Phlox (*Phlox* spp.): Leaf spot (*Septoria divaricata*).
Pine, Loblolly (*Pinus taeda*): Rust (*Coleosporium delicatulum*).
Pine, Longleaf (*Pinus palustris*): Rust (*Cronartium cerebrum*); Rust (*Coleosporium delicatulum*); Rust (*Coleosporium Ipomoeae*).

Pine, Shortleaf (*Pinus echinata*): Rust (*Coleosporium delicatulum*); Rust (*Coleosporium inconspicuum*).

Plum (*Prunus domestica*): Plum pockets (*Exoascus Pruni*).

Plum, Wild (*Prunus americana*): Black knot (*Dibotryon morbosum*); Brown rot (*Sclerotinia fructicola*); Hypertrophy (*Exoascus mirabilis*).

Potato (*Solanum tuberosum*): Black leg (*Bacillus phytophthorus*); Early blight (*Alternaria Solani*); Late blight (*Phytophthora infestans*); Scab (*Actinomyces scabies*); Scab, Powdery (*Spongospora subterranea*); Southern blight (*Sclerotium Rolfsii*); Stem rot (*Corticium vagum*); Wilt (*Fusarium oxysporum*); Black heart (Non-par.); Mosaic (Undet.).

Princess tree (*Paulownia tomentosa*): Leaf spot (*Phyllosticta Paulowniae*).

Privet (*Ligustrum* sp.): Leaf spot (*Cercospora Ligustri*).

Raspberry (*Rubus* sp.): Cane blight (*Leptosphaeria Coniothyrium*); Mosaic (Undet.).

Rose (*Rosa* spp.): Anthracnose (*Gloeosporium Rosae*); Black spot (*Diplocarpon Rosae*); Brown canker (*Diaporthe umbrina*); Crown gall (*Bacterium tumefaciens*); Mildew (*Sphaerotheca pannosa*).

Rye (*Secale cereale*): Anthracnose (*Colletotrichum graminicola*).

Snapdragon (*Antirrhinum Majus*): Rust (*Puccinia Antirrhini*).

Sorghum (*Holcus sorghum*): Loose kernel-smut (*Sphacelotheca cruenta*): Rust (*Puccinia purpurea*).

Soybean (*Soja Max*): Bacterial blight (*Bacterium Sojae*); Leaf spot (*Cercospora cruenta*); Southern blight (*Sclerotium Rolfsii*); Mosaic (Undet.).

Squash (*Cucurbita maxima*): Southern blight (*Sclerotium Rolfsii*).

Strawberry (*Fragaria* sp.); Leaf spot (*Mycosphaerella Fragariae*).

Sugar cane (*Saccharum officinarum*): Eye leaf spot (*Helminthosporium Sacchari*).

Sweet pea (*Lathyrus odoratus*): Anthracnose (*Colletotrichum Pisi*); Root rot (*Rhizoctonia Solani*).

Sweet potato (*Ipomoea Batatas*): Black rot (*Ceratostomella fimbriata*); Charcoal rot (*Sclerotium bataticola*); Leaf spot (*Phyllosticta Batatas*); Rust (*Coleosporium Ipomoeae*); Stem rot (*Fusarium Batatatis* and *Fusarium hyperoxysporum*); Mosaic (Undet.).

Sweet William (*Dianthus barbatus*): Rust (*Puccinia Arenariae*).

Tomato (*Lycopersicum esculentum*): Leaf spot (*Septoria Lycopersici*); Nailhead spot (*Macrosporium Tomato*); Southern blight (*Sclerotium Rolfsii*); Stem rot (*Corticium vagum*); Wilt (*Fusarium Lycopersici*); Blossom end-rot (Non-par.).

Turnip (*Brassica Rapa*): Black rot (*Bacterium campestre*); Leaf spot (*Colletotrichum Higginsianum*); Leaf spot (*Macrosporium herculeum*); Soft rot (*Bacillus carotovorus*); White rust (*Albugo candida*).

Velvet bean (*Stizolobium* sp.): Leaf spot (*Phyllosticta Mucunae*); Stem rot (*Corticium vagum*).

Violet (*Viola odorata*): Southern blight (*Sclerotium Rolfsii*).

Watermelon (*Citrullus vulgaris*): Downy mildew (*Peronoplasmopara cubensis*); Southern blight (*Sclerotium Rolfsii*); Wilt (*Fusarium niveum*).

Wheat (*Triticum aestivum*); Anthracnose (*Colletotrichum graminicola*); Glume blotch (*Septoria nodorum*); Leaf rust (*Puccinia triticina*); Loose smut (*Ustilago Tritici*); Stem rust (*Puccinia graminis*).

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NOTES AND BRIEF ARTICLES

Through some careless slip there has been a duplication of numbers in the plates for volume 22 of MYCOLOGIA. The number 13 has been repeated. Also the plates for the November–December issue should have been numbered 32–35 instead of 22–25. The volume, therefore, contains 36 plates instead of 25, as is indicated by the numbers. It is unfortunate that this error was not detected in time to prevent it.

The Mycological Department of The New York Botanical Garden has recently mounted and filed in book form nearly 10,000 specimens of fungous exsiccati. Most of these are duplicates of specimens already distributed through the collection. However, as it is often difficult to locate these specimens by number it is very convenient to have duplicate sets filed in serial order. It is hoped that eventually all published sets of exsiccati may be so arranged.

FITZPATRICK'S PHYCOMYCETES [1]

As the amount of work on the fungi increases year by year, mycologists and plant pathologists find themselves more and more in need of adequate surveys of the main fungous groups. Realizing that the situation now demands an intensive treatment of each group, Dr. Fitzpatrick has started filling the long felt need by this volume on the Phycomycetes, a class of fungi which merits a more extended discussion than was possible in the helpful but necessarily restricted chapters in recent volumes by Gäumann, and by Gwynne-Vaughan and Barnes, on the fungi as a whole. The wisdom of Dr. Fitzpatrick's method of procedure is shown by the amount of material which he has presented in this volume and it is to be hoped that now he will go on and take up the other groups in like manner.

The form of the book accords with that adopted for others of

[1] Fitzpatrick, H. M. The Lower Fungi—Phycomycetes. 331 pages, illustrated. McGraw-Hill Book Company, Inc. New York, N. Y., 1930. Price $4.00.

the recent McGraw-Hill publications in botanical sciences. The volume is a neat, compact one, firmly bound, attractively covered and lettered, printed in a clear, easily read type on paper not too heavy, yet thick and smooth enough to take illustrations well. And the book of 331 pages, abundantly illustrated, is issued at a price not beyond the means of the college student.

Following the brief preface in which the purpose of the volume is given, Chapter I, an introduction of 18 pages, discusses the nature, development, characteristics and relationships of the several groups of Thallophytes as a background for the specific study that follows, and Chapter II, comprising 20 pages, covers such general points as the origin of the Phycomycetes, the nature of the thallus and of the asexual and sexual methods of reproduction, the classification of the group, its basis, and the orders recognized in this classification, while at the end of the book a final Chapter XI in 12 pages discusses the phycomycetous affinities of the Hemiascomycetes, taking up the possible significance of various forms which have been stressed as important in this interesting but much disputed question.

Chapters III to X, inclusive, comprise discussions respectively of the Chytridiales, 11 pages; the Ancylistales, 11 pages; the Blastocladiales, 6 pages; the Monoblepharidales, 7 pages; the Saprolegniales, 34 pages; the Peronosporales, 38 pages; the Mucorales, 41 pages; and the Entomophthorales, 17 pages. In each of these, keys to the families and genera are given, the salient characteristics of the order and of its several families are presented, and the structure, development, life history, importance, and relationship of the various genera are taken up. As can be seen, some orders are emphasized more than others and are given a much more thorough discussion because of their unusual scientific interest or their outstanding economic importance.

One very useful feature of the book is the provision of a separate bibliography at the close of each chapter, a procedure which makes it easier for the student to gain a knowledge of the literature dealing with any group, facilitates his looking up material for additional reading and gives him a readily accessible source list for consultation.

The index at the end of the book is satisfactorily detailed and

extensive, adequately meeting the needs of a reference book of this type.

The author takes up the terms which are used in the text and explains them when they are first encountered, thus avoiding a formal glossary and presenting the terms and their definitions in the context in which they belong.

The illustrations are numerous, 112 figures, mostly zinc cuts photographically reproduced from line drawings, a few half-tones from previously published plates, and several illustrations presented in this book for the first time.

In a book review such as this, when the purpose, the form, and the scope of the volume have been covered and a general survey of the content has been given, it seems an established custom to turn next to points of criticism.

If this procedure is to be followed, attention should be called to the fact that the discussion of the "zygospores" and their method of formation in *Dispira americana*, as attributed to Dr. Thaxter on page 271, in reality describes and figures the "sikyospores" of the parasitic, sporangial, mucoraceous genus *Parasitella*. The perpetuation of this error is unfortunate, the more so since, in 1903, Blakeslee in his "Sexual Reproduction in the Mucorineae," page 245, had already explained, "Professor Thaxter informs me that the zygospore-like bodies found by him in connection with his cultures of *Dispira* were probably accidentally associated with it, and that they are doubtless referable to the genus *Parasitella* recently published by Bainier ('03)," while Burgeff in his paper of 1924 (included by Fitzpatrick in the bibliography following this chapter) unmistakably describes and figures these "sikyosporen" of *Parasitella*. Moreover, in accepting Lendner's relegation of *Parasitella simplex* Bainier 1903 to *Mucor parasiticus* Bainier 1884, Fitzpatrick must have seen Lendner's Figure 24 of the "tuberosites" or "renflements" of the parasite, recognizable as the so-called "zygospores" of *Dispira* even though Lendner's portrayal had the crudeness of some primitive caveman, or of the most astigmatic of moderns. Incidentally, the wisdom of accepting Lendner's relegation might be questioned, as Bainier's later judgment probably should supersede

his earlier one and Burgeff, Blakeslee and others who recently have worked with *Parasitella* retain it as a distinct genus.

Also it is unfortunate that in the subgenus *Sphaerosporangium* (p. 198) there are included a number of species of *Pythium* characterized by lobose or filamentous sporangia wholly distinct from the true *Sphaerosporangium* type.

Then, too, it hardly seems just that the Endogoneae, recognized as a distinct family in the most recent revision by R. Thaxter, should be relegated to the ignominious position of an appendage to the Mortierellaceae, scantily noted in connection with *Mortierella*, and omitted from the key to the families.

Moreover, it is perhaps regrettable, when more than half a page is given to the theoretical explanation of the mechanism of *Pilobolus*' orientation to light, that there is no mention of the significant experiments by Jolivette and others on this phenomenon, or by Blau and others on the related problem of the influence of light on the growth and orientation of *Phycomyces*.

Likewise it is unfortunate that in discussing the amphigynous type of antheridia in *Phytophthora* (p. 203) no credit is given to Dastur's paper of May 1913 which shares with Pethybridge's paper of March 1913 the distinction of calling attention to the extraordinary method of forming these bodies.

As several of the excellent figures from it aid in illustrating the Peronosporales, the lack of reference to Schwartz's "Parasitic Fungi of New Jersey" must have been merely an oversight. The significant papers by Kolkwitz (Ber. d. D. Bot. Ges. 1901–1903) on artificial culture of *Leptomitus* might well be included in the bibliography, while mention of Morini's *Phycomyces pirottianus* calls for reference to his "Note Micologiche" in Malpighia 10, 1896.

The genus *Coenomyces* might well be mentioned, not because of the possible phylogenetic significance stressed by Deckenbach, who described it (Flora 1903), but because of its interesting habitat, distribution and parasitism.

In the brief discussions of Scherffel's work, lack of reference to some of the extraordinary points brought out arouses a suspicion that Fitzpatrick, like the present reviewer, has found those papers almost Brefeldianly hard reading.

The illustrations, on the whole, are excellent. Some, however, have suffered at the hands of the engraver, either through carelessness in cutting out the figures on the block, as in Figs. 51 and 65a, or through blotchy rendering of lines and stippling originally distinct, as in Figs. 52, 63, and 76. Also, some fall far short of the excellence of the originals from which they have been taken; for example, compare Figs. 55*a–c* of *Aplanes* and Fig. 59 of *Pythiopsis* with the lithographs of de Bary's Taf. 9 in the Botanische Zeitung for 1888, or Figs. 61*e*, *f*, of *Achlya* with the wood cuts of DeBary's Fig. 70 in the 1887 "Comparative Morphology," or Fig. 70 of *Pythiogeton* with Von Minden's Plate 7 in his "Submerser Phycomyceten" of 1916. In one or two cases errors have crept in during preparation so that the figures are actually incorrect. For example, in Fig. 60 of *Saprolegnia*, the proliferated sporangia at *a* show inaccuracies in the size and orientation of the escape pores and in the position of the basal wall, features correctly represented in Plate 9, Fig. 1, of Coker, 1923; and in *b* through line-shading the walls of the oöspores and oögonium, the accurate outlines of Coker's Plate 11, Fig. 1, have been lost; while in *e* the wall thickness of the non-motile spores and the shape and ciliation of the zoöspore have lost the accuracy of Marshall Ward's Plate 28 of 1883. Moreover, in *c* of this same Fig. 60, the obvious error in thickness of the sporangium wall, inherited through Atkinson's figure of 1909 from the original ancestral Fig. 134 of Atkinson's "Elementary Botany" of 1898, regrettably is perpetuated. Also, Figs. 78 to 80, although very cleanly reproduced, would perhaps be more effective if the tops of the conidiophores were up instead of down, as in their present position they are more difficult to apprehend even though one realizes that in many instances it is in this very position that they grow from the leaves.

All of us, alas, have found that rarely do we publish even a short paper without at least one typographical error; in this book there are many still to be corrected. Pages such as 70 or 76 probably lead in number of these, but page 240 with "gaemtangia" and pages 247 and 248 with "*Syzgites*" deserve recognition for novelty at least. Attention should be called to the correctness of Piptocephalidaceae rather than Piptocephalaceae, Brefeld's work on *Conidiobolus utriculosus* (not *utriculosis*) was

in Mycologische Untersuchungen 6, not 4, Sparrow's note on "Rotifer Capturing Phycomycetes" was in 1929, not 1919, and the date and reference for the establishing of the genus *Sclerospora* should be Hedwigia **18:** 87, 1879.

Throughout the book "corresponds with" and "corresponds to" are used with large-hearted impartiality; under Fig. 54, "Magnification of *a* and *e* is the same; that of others same but higher" leaves the reader somewhat bewildered; "monoplanetic as regards form" for *Pythiopsis* is rather obscure; while on page 198 the sentence, "The fungus *Rheosporangium aphanidermatum*, cause of a disease of radish known as black-root and damping off of beet seedlings," as it now stands leaves one feeling that there is little hope for the radish thus doubly afflicted.

The term aboospore, which apparently is used here for the first time, seems somewhat ill chosen, sure to cause confusion when received by ear during hurried lectures, and to the eye appearing as if it had something to do with a cry of derision. Moreover, the word planogamic is of doubtful etymology, planogametic perhaps being preferable.

If, in the foregoing cirticism, I have seemed overzealous in pointing out errors, imperfections and omissions, let it be remembered I am convinced that the value of this book soon will necessitate a second edition, and toward such a revision these suggestions will be helpful. Also in critically scrutinizing the book I have learned much; for example, from looking up the original description of *Papulaspora* I have learned that we have been spelling this name incorrectly in this laboratory for years. Moreover, I am aware that this, Dr. Fitzpatrick's first book, represents a total of exactly one book more than I (or several other critics) have written as yet. The book is one of substance and worth. We are finding it a useful and valuable compendium of material that has not been made accessible hitherto. Furthermore it is to be commended for the able and impartial presentation of such controversial questions as the possible phylogeny of the Phycomycetes, and the possible relationships between the Ascomycetes and Phycomycetes. Very helpful also are the clarifying discussions of the disputed distinctions between *Pythium* and *Phytophthora* and between conidia and sporangia, in their

relation to the influence of external conditions on methods of discharge or germination. It seems certain that this volume will stimulate researches into the many significant problems the Phycomycetes present and it is to be hoped that Fitzpatrick may be induced to take up the higher groups of fungi in the same way.

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ANNOUNCEMENT

Doctor Jacob E. Lange, well known Danish student of the mushrooms, will arrive in New York the middle of August for several weeks of collecting in the northeastern United States and eastern Canada. He wishes to study especially the parallelism and identity of American and European species of Agaricaceae. A definite itinerary has been arranged. Inquiries regarding its details may be directed to Doctor C. W. Dodge at Pawlet, Vt.

From August 28 to September 2 inclusive Doctor Lange will be at Ithaca, New York. The region about Ithaca is especially interesting to him because Atkinson published over a period of years on locally collected materials. Fungus forays will be made daily to nearby points of interest in the effort to see a large number of species.

In order that the conceptions of species as held by Peck, Atkinson, Kauffman and other older American workers in the group may be clearly understood, it is imperative that Doctor Lange be enabled to exchange ideas in the field with their students. To this end American mycologists, especially those interested in mushrooms, are urged to come to Ithaca and cooperate in making these forays a success. Students with only a minor interest in the Agaricaceae will also be welcomed, and the forays will be arranged in such a manner that collecting in other groups will be fruitful. Incidentally, the Atkinson herbarium has been put in good order in recent years, and is now available for consultation in the new Plant Science Building at Cornell University.

Those who plan to attend the Ithaca forays are asked to notify the undersigned at as early a date as possible. Arrangements will be made for lodging, meals, and transportation at reasonable rates. Information concerning these items or other features of the plans for the forays will be gladly given.

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